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ADDRESS TO THE SOCIETY [1]

BY SIR R. S. PEARSON

IT has been my privilege to act as your President for a second year, and I think that I am not overstating the case when I say that forestry throughout the world, has, during this time, never gone through a more dangerous period. Fortunately, in our country, the nation having faced the crisis and balanced its budget in a time of national emergency, the Government Forest Service has not been vitally affected, though the pace at which reafforestation has been carried out has of necessity been slowed down. In other parts of the Empire the Services have been affected in varying intensity, by cutting down the staff and expenditure by 25 per cent. or more, while in some of the smaller colonies the Services have been threatened with complete extinction. That such a short-sighted policy should prevail is nearly inconceivable and it is the duty of every forester to counter it by every means possible, and may I suggest especially that of members of our Society. I have ventured to stress this point as the danger is real, and one affecting the interests of not only forestry but also of individual nations.

Our Society has no doubt suffered to a small degree from the bad times, in that the increase in the number of members might have been greater had not possible candidates felt that they could not afford to join at this juncture; on the other hand, the increase in our membership is not unsatisfactory, having, in spite of casualties, risen in the last twelve months. Might I ask all members to bring the Society and its Journal to the notice of such of their friends who, according to the rules, are eligible to join. In my address of last year I urged the necessity of foresters periodically getting together. I suggested that the annual excursion was one of the occasions on which we could most profitably exchange views, 'talk shop', and get to know each other better. Unfortunately, the number of members who promised to attend the last meeting was so small that it had to be called off. This year a most attractive programme has been arranged for our excursion, which will take place in the neighbourhood of Elgin, and is scheduled to last from the 22nd to the 26th of May, when the regeneration and treatment of Scots pine will be studied. I hope that every member who can possibly get off will attend.

Turning now to the more important events which have occurred during the last twelve months, the Ottawa Conference and its effect on the timber trade of this country must be mentioned; equally, the effect of the tariff, though this is not the time to discuss such subjects. A point on which one is on safer ground is the cry of 'Buy British', for never was there a time when the public was so enthused with the idea that it was their duty to help their country and the Empire generally. The obvious moral is 'Don't miss the opportunity to purchase British timber'.

I know that all members will join me in congratulating the Royal English

[1] Delivered at the Sixth Annual Meeting of the Society held at Kew on 17 February 1933.

Forestry Society on attaining its Jubilee. During its career they have greatly helped to bring forestry into the picture in England, and this year Mr. Ackers, their President, has done much towards improving the standard for which his Society gives certificates and diplomas in wood-workmanship, and to further marketing of estate produce.

As I stated above, the Forestry Commission have not been hit so hard by the economic crisis as forest services in other countries, in that their staff has not suffered, though recruitment has been practically stopped. Their activities have, however, been curtailed and the planting programme reduced to 20,000 acres per annum; land acquisition cut down in proportion; a considerable reduction in the number of forest workers holdings to be made; and other similar savings. The total area of State land planted up to September 1931 was 188,985 acres (of which 93 to 94 per cent. was softwoods) and that assisted on private lands 85,386 acres. On the Government areas in 1931, 37 per cent. was planted with Scots and Corsican pines, 32 per cent. Sitka and Norway spruce, 13 per cent. larch, and 3 per cent. Douglas fir. I give these figures as they are of interest. To comment on them is not possible, as a variety of circumstances, as all foresters know, must govern the consideration of selection. I should like, however, to stress one point, which to my mind is of vital importance, and that is, whatever species is selected, the necessity of producing sound, clean merchantable timber. Correct silvicultural methods may attain these ends, and in any case, whatever other steps are taken it is on correct methods of treatment that we must depend. To assist, pruning may be adopted, and in this connexion I have to congratulate the Forestry Commission and Mr. Guillebaud, their Chief Research Officer, on having inaugurated in 1931 a detailed investigation to determine the best tools and equipment with which to prune stems. Trials have been carried out on four species growing in forty sample plots, situated in different localities, to ascertain the cost of such operations; to determine the intensity and age at which pruning should be carried out; eventually to provide samples for the examination of timber produced after pruning with different types of tools and at different ages, and to study the effect of pruning on growth. These experiments should produce interesting and very valuable information.

The first part of a major investigation on the incidence of an unusual form of wart rot in oak was completed. The rot is caused by *Stereum spadiceum* and works down from the branches into the stem. Nearly 2,000 trees were cut into short lengths and the position and volume of the rot determined. All the evidence points to this disease being primarily a result of excessive thinning in the early youth of the oak stands, followed by the death of the large lateral branches when canopy was again allowed to form.

Well-equipped meteorological stations have been established in three forests: Thetford in Norfolk, Benmore in Argyllshire, and the Forest of Dean in Gloucestershire. At each station blocks of trees of three broad-leaf species and three conifers have been planted and observations are made during the growing season on time of flushing, shoot growth, &c.

Another investigation, which has lead to practical results concerning the control

by sulphur sprays of *Meria laricis*, which causes leaf-cast of larch in nurseries, was brought from the experimental stage to general practice, with satisfactory results.

In the region of timber research a very considerable amount of useful information has been collected. Of items of interest may be mentioned the experiments with home-grown treated pitprops, placed in mines in England and Scotland, which show that none of the 365 treated props were in any way decayed, after 2¾ years, whereas 23 out of 36 of the untreated props were defective, or have been removed. Much has been written in the papers of late about cricket-bat willow, naturally a popular subject, but one about which opinions are widely divergent, except probably amongst the buyers, bat-makers, and one or two individual growers and experts. The more one goes into the question the greater one finds the complexity of the problem. To make a start on the investigation, the Forest Products Research Laboratory, in co-operation with the Imperial Forestry Institute, Oxford, and Messrs. Surridge—the well-known bat-makers—has purchased carefully selected trees of true *Salix caerulea*, grown in three different localities and on two types of soil in each locality, to endeavour to find out the effect of locality on the quality of the timber. After the necessary tests have been carried out, it is proposed to attempt to correlate the results of the mechanical tests with the results of practical tests and similarly with the growth features of the timber. If the results of the mechanical tests prove that they truly indicate the quality of the wood suitable for cricket bats, a sound basis of working will have been determined for further investigations. Another line of investigation has been started, to which I attach much importance, which aims at evolving sound scientific methods for carrying out tests to determine the working qualities of wood, a much neglected side of Forest Products Research. I have only had space to mention a few cases of recent research in silviculture and timber, but must ask you to forgive me for adding one further item bearing on the latter, and that is the question of grading. The British Standards Institution are now engaged on formulating a grading scheme for softwoods, and the Imperial Institute, London, one for hardwoods. These are subjects fraught with difficulties, but I feel that until we have grading rules in this country we shall not be able to co-ordinate our trade effectually.

It is with the greatest regret that I have to record the death of three distinguished members of our Society—J. F. Annand, G. Home, and, quite recently, that of H. A. Pritchard—who were all on the staff of the Forestry Commission. Obituary notices on each of these distinguished officers have appeared in the last number of our Journal, and I know that their relations and many friends have the sincere sympathies of all members of our Society.

In conclusion, permit me to express my grateful thanks to the members of the Council, who have assisted with their good advice and support. I feel that I owe a special debt of gratitude to our Treasurer and Secretary, Mr. R. Angus Galloway, for the very helpful way in which he has handled business and made matters run smoothly. I know that I voice the opinion of the Society when I say that its good name and standing owes much to the excellency of its Journal, and for this we have to heartily thank Dr. H. M. Steven.

CHANGES AMONGST WELL-KNOWN TREE NAMES

BY W. DALLIMORE

SYNONYMOUS plant names have been a source of trouble and confusion ever since plant names were given. The confusion has harassed botanists and cultivators alike, but botanists have been the more sorely tried, inasmuch as they concern themselves with all kinds of plant life whereas cultivators' interests are limited.

The question will doubtless arise, 'If the position is harmful to botanists why did they create it?'. This is easy to answer. Botanists in different parts of the world, unknown to each other, worked upon similar groups of plants, often rare and newly introduced kinds: all the material they had was dried specimens, and the same plant was unwittingly given two or more names by different workers. Also, in days when communication between distant countries was difficult, botanists frequently had insufficient material to name certain plants: interchange of specimens and views was out of the question, therefore names were given which later on had to be changed on account of increased knowledge concerning the group. Trained botanists alone have not been responsible for the creation of synonymous plant names, because names have sometimes been given to suit the fancy of patrons of horticulture and gardening enthusiasts, all of which have added to the confusion. Other factors have been at work, but these will suffice to indicate how the position arose.

The growing confusion and the possibilities of worse to come was apparent to Linnaeus in the eighteenth century, and he made a very good start in the way of simplification by abandoning the cumbrous method practised at that time, whereby a number of Latin descriptive words were given to a plant, by giving a name consisting of two words to each species—these are the generic name and a specific name, corresponding to the surname and Christian name of a human being, but placing the surname or generic name first.

As an instance of what is meant, Linnaeus reduced the name of the common elderberry from *Sambucus fructu in umbella nigro* C. Bauhin, or *Sambucus caule arboreo floribus umbellatis* Royen, two of the names then in vogue, to *Sambucus nigra* Linn. This was a great step forward, and the system soon became popular, but Linnaeus had to work upon very incomplete material and many of his early decisions have necessarily suffered revision. For instance he placed the larch, fir, spruce, and pine in the genus *Pinus*. Botanists at later dates could not accept that grouping and founded other genera. On the removal of certain species from *Pinus* to the new genera some of them were given new specific names. Not only did this go on with species described by Linnaeus, but also with those of other botanists. Within a hundred years of the publication of Linnaeus's *Species Plantarum*, the need for some definite understanding regarding the determination of right and wrong names had arisen, and in 1867, at an

International Botanical Congress at Paris, it was agreed that the year 1735 should be accepted as the starting-point for the nomenclature of genera and 1753 for species. This went on until 1905, when suggestions for revised Rules and Recommendations governing nomenclature were submitted to an International Botanical Congress at Vienna.

These Rules and Recommendations dealt very fully with the priority of names of both genera and species, the latter receiving more attention than previously. At this Congress two major suggestions concerning species were considered: (1) that the oldest specific name dating back to 1753, the date of publication of Linnaeus's *Species Plantarum*, ed. 1, be accepted; (2) that the priority of specific names should only date back to the time when a species was placed in its right genus. Eventually it was agreed that priority for both genera and species should date from 1753, the particular rule reading as follows: 'Botanical nomenclature begins with the *Species Plantarum* of Linnaeus, ed. i (1753), for all groups of vascular plants. It is agreed to associate genera, the names of which appear in this work, with the descriptions given in the *Genera Plantarum*, ed. v (1754).'

It was foreseen that the substitution of well-known generic names for others that were little known would create a vast amount of confusion, therefore an agreement was reached that some 400 well-known generic names that would be affected by priority rules should be conserved. Unfortunately the same decision was not reached with specific names.

Some old specific names were used as generic names, otherwise the oldest specific name from that date holds good, in accordance with the Rules of Nomenclature. Thus Linnaeus in 1753 named the common larch *Pinus Larix*. In 1768 Miller separated it from Pinus and named it *Larix decidua*. De Candolle in 1805 gave the name of *Larix europaea*—in many ways a better name than *L. decidua*—but according to the rule of priority the name of *L. decidua* must be used. Karsten in 1882 made a new combination of names and called the common larch *Larix Larix*, using the specific name of Linnaeus (the earliest) with the generic name of Miller, but such combinations are so distasteful to many workers that they were treated as invalid, hence the next specific name 'decidua' is adopted under the International Rules.

As the results of the 1905 agreement plant cultivators found that a number of very well-known, and in many cases very appropriate, specific names were being changed for obscure names some of which were less appropriate than those that had been in use. In many instances they rebelled against the use of these names, and hoped that when the Rules concerning plant nomenclature again came under revision a number of well-known specific names would be conserved. There were botanists also who would have liked to have seen certain specific names conserved, and numerous lists of such names were presented to the International Botanical Congress at Cambridge in 1930. However, the number of names submitted for conservation was so great, and some of the cases made for the retention of the names were so weak, that the Congress decided against the conservation of specific names. As it appears to be unlikely

that future consideration will lead to any alteration of this decision, it is now wise to accept the position and bring up the younger generation of foresters and others interested in the cultivation of trees in the use of the correct names, even though they may create difficulties for older people.

It is not always easy to find out which of several names should be used. Running down names of species entails endless work. Even when the starting-point has been reached the plant may have been described in such meagre fashion that it is sometimes doubtful whether the earliest name should be accepted at all, owing to uncertainty in its application. Plants are supposed to be properly described before a name becomes valid, and from 1932 onwards the part of the description containing the salient characters of the plant must be in Latin, although the main body of the description may be in any language.

When it is discovered that two genera are included under one name, the original name must be kept for one of them, and the other genus must receive a new name. Also, when it is found that two species appear under one name the original name must be retained for one species and the other must be given a new name.

It sometimes happens also that a name has been used in different ways by different people and so has become a permanent source of confusion. In such cases the name is abandoned altogether and the next oldest valid specific name adopted. A special list of these names is to be published.

This question will doubtless occur, 'How do botanists know when they have found the earliest name, when the names have been published over so many years in the books of all nations?' To meet this need, which became very urgent during the latter half of last century, the preparation of the *Index Kewensis* was undertaken. The earlier volumes were compiled by the late Dr. B. Daydon Jackson, and from the title-page we learn that it is an Enumeration of the Genera and Species of Flowering Plants from the time of Linnaeus to the year 1885 inclusive, together with their author's names, the works in which they were first published, their native countries and their synonyms. It was compiled at the expense of Charles Robert Darwin, under the direction of Sir J. D. Hooker. The first four volumes were prepared during the period 1886–95, and subsequent quinquennial supplements carry the enumeration of names to 1925, and the work is still going on. It is difficult to estimate the number of plant names dealt with in this work, but it is certainly not less than 800,000.

The work is of untold value to botanists in general but it is most highly appreciated by those who are engaged upon research in taxonomy and nomenclature.

Name changes are not always nomenclatural. Taxonomic changes are frequent, and unfortunately changes due to taxonomy cannot be settled in the same way as nomenclatural changes. All botanists do not see alike as to the limiting characters of genera and species, and it is impossible to have rules to settle such questions: every one must use his own judgement or the judgement of the author in whom he has most faith when name changes are due entirely to classification. A case in point is *Cupressus* and *Chamaecyparis*. Many

botanists divide the Cypresses into these two genera, others are content to include all the species under *Cupressus*, but to group one set of species under the subheading *Eucupressus* and another set under *Chamaecyparis*. Wrong classification or identification of certain cypresses also led to confusion. *Cupressus pisifera* was originally named from incomplete material, largely shoots with the juvenile type of foliage, and it was made the type of a new genus *Retinispora*. Later it was found out that a mistake had been made, but the name of *Retinispora* had become widely spread and exists to this day in some places, although as a generic name it is obsolete. *Thujopsis borealis* was a name wrongly given to *Cupressus* (*Chamaecyparis*) *nootkatensis*, and although the correct name has been known for a very long time, *Thujopsis borealis* still appears in some catalogues. There are many other instances of a similar nature.

I am greatly indebted to Miss M. L. Green, B.A., F.L.S., one of the specialists in nomenclature at Kew, for advice in the preparation of these notes.

In the following list attention is directed to the name changes that are most likely to affect foresters and other cultivators in the British Isles.

CONIFERS.

Common name.	*Correct scientific name.*	*Well-known synonymous name.*
Silver fir	*Abies alba* Mill.	*Abies pectinata* DC.
Nikko fir	„ *homolepis* S. & Z.	„ *brachyphylla* Maxim.
Santa Lucia fir	„ *venusta* K. Koch	„ *bracteata* Nutt.
Webb's Himalayan fir	„ *spectabilis* Spach	„ *Webbiana* Lindl.
Chile pine	*Araucaria araucana* K. Koch	*Araucaria imbricata* Pav.
Cedar of Lebanon	*Cedrus libanotica* Link	*Cedrus Libani* Loud.
Chinese fir	*Cunninghamia lanceolata* Hook.	*Cunninghamia sinensis* R. Br.
Patagonian fir	*Fitzroya cupressoides* F. M. Johnston	*Fitzroya patagonica* Hook. f.
Tamarack	*Larix laricina* K. Koch	*Larix americana* Michx.
European larch	„ *decidua* Mill.	„ *europaea* DC.
Japanese larch	„ *Kaempferi* Sarg.	„ *leptolepis* Murr.
Dahurian larch	„ *Gmelini* Pilger	„ *dahurica* Turcz.
White spruce	*Picea glauca* Voss	*Picea alba* Link
European spruce	„ *Abies* Karst.	„ *excelsa* Link
West Himalayan spruce	„ *Smithiana* Boiss.	„ *Morinda* Link
Black spruce	„ *mariana* B. S. & P.	„ *nigra* Link
Austrian pine	*Pinus nigra* var. *austriaca* Asch. & Graebn.	*Pinus laricio* var. *nigricans* Parl.
Calabrian and Corsican pine	*Pinus nigra* var. *calabrica* Schneid.	„ *laricio* var. *corsicana* Hort.
Crimean pine	„ *nigra* var. *caramanica* Rehd.	„ *laricio* var. *Pallasiana* Ant.
Short-leaf pine	„ *echinata* Mill.	„ *mitis* Michx.
Mountain pine	„ *mugo Turra*	„ *montana* Mill.
Large Mountain pine	„ *mugo* var. *rostrata* Hoopes	„ *montana* var. *uncinata* Willk.
Monterey pine	„ *radiata* D. Don	*Pinus insignis* Dougl.
Chinese pine	„ *tabulaeformis* Carr.	„ *sinensis* Lamb.
Knobcone pine	„ *attenuata* Lemmon	„ *tuberculata* Don
Douglas fir	*Pseudotsuga taxifolia* Britt.	*Pseudotsuga Douglasii* Carr.
Western Arborvitae	*Thuja plicata* D. Don	*Thuja gigantea* Nutt., and *T. Lobbii* Hort.

Common name.	*Correct scientific name.*	*Well-known synonymous name.*
Western hemlock	*Tsuga heterophylla* Sarg.	*Tsuga Albertiana* Sénécl. and *T. Mertensiana* Carr. not Sarg.
Mountain hemlock	„ *Mertensiana* Sarg. not Carr.	*T. Hookeriana* Carr. and T. *Pattoniana* Sénécl.
Himalayan hemlock	*Tsuga dumosa* Sarg.	*T. Brunoniana* Carr.
	BROAD-LEAVED TREES	
Caucasian wing-nut	*Pterocarya fraxinifolia* Spach	*Pterocarya caucasica* C. A. Mey
Silver birch	*Betula pendula* Roth	*Betula verrucosa* Ehrh. *B. alba* Linn. in part.
„ „	„ *pubescens* Ehrh.	*Betula alba* Linn. in part.
American beech	*Fagus grandifolia* Ehrh.	*Fagus ferruginea* Ait.
Red oak	*Quercus borealis* Michx.	*Quercus rubra* Duroi not Linn
English oak	„ *Robur* Linn.	*Q. pedunculata* Ehrh.
Mountain elm	*Ulmus glabra* Huds. not Mill.	*Ulmus montana* With.
English elm	„ *procera* Salisb.	„ *campestris* Mill.
Dutch elm	„ *hollandica* Mill.	„ *major* Sm.
Smooth-leaved elm	„ *foliacea* Gilib.	„ *nitens* Moench
Keaki	*Zelkova serrata* Makino	*Zelkova acuminata* Planch.
„	„ *carpinifolia* K. Koch	„ *crenata* Spach
Osage orange	*Maclura pomifera* Schneid.	*Maclura aurantiaca* Nutt.
Yulan	*Magnolia denudata* Desrouss.	*Magnolia conspicua* Salisb.
Common laburnum	*Laburnum anagyroides* Med.	*Laburnum vulgare* J. S. Presl
Tree of Heaven	*Ailanthus altissima* Swingle	*Ailanthus glandulosa* Desf.
Sugar maple	*Acer saccharum* Marsh	*Acer saccharinum* Wangh. not Linn.
Silver maple	„ *saccharinum* Linn. not Wangh.	„ *dasycarpum* Ehrh.

THE SIGNIFICANCE OF CROWN-LENGTH IN LARCH PLANTATIONS

BY SIR ROY ROBINSON

INTRODUCTION.

DURING the years 1917–19 data were systematically collected by temporary sample plots as to the rate of growth of conifers in Great Britain. The method of procedure and the results are stated in two bulletins (1) and (2). One item in the survey, to which little reference is made in the bulletins, is 'Crown-length', which was determined for nearly all the plots measured. The writer started to investigate the subject as a diversion during the London air raids, but the data were then incomplete; the results appeared to follow no defined laws, and the raids ceased. The subject was accordingly dropped, and although the measurement of crown-lengths has been continued in connexion with the numerous permanent sample plots established by the Forestry Commission, the data have never been systematically correlated. It was with the object of ascertaining whether such work would be justified that the writer recently reviewed the temporary sample plots, choosing for the purpose the larch because, being a sensitive light demander, it was most likely to register changes in crown-length due to variation in silvicultural treatment.

DATA EMPLOYED.

For sample trees used in the determination of the volume of sample plots, the height of the lower crown (L.C.) was measured from the butt to the lowest living branch, and the height of the upper crown (U.C.) from the butt to the lowest living whorl of branches. The instructions continued:

'The crown-length per cent. is the proportion of the whole length of stem which is covered by living crown.

'For the individual tree the mean of the upper crown (U.C.) and the lower crown (L.C.) is to be subtracted from the total length of the tree, and the result divided by the total length, i.e.

$$\text{Crown-length per cent} = \frac{L - \frac{UC+LC}{2}}{L} \times 100.$$

'For the whole crop the crown-length is to be determined as follows:

'The crown-length per cent. is plotted against the quarter girth for each sample tree, and the crown-length corresponding with the mean quarter girth of the plot read off.'

In addition to the usual statement prepared for each sample plot (age, height, quarter girth, number of stems per acre, basal area per acre, form factor cubic feet per acre, crown-length percentage and bark percentage) each summary

contains a note headed 'stocking'—whether the crop was fully, under-, or overstocked, the general condition of the canopy and of the crowns.

As a first step the individual plots were separated into four classes according to the description under the head 'stocking'. The classes and typical entries are stated below:

1. *Normally stocked*, e.g. 'fully stocked; canopy good; crowns good'.
2. *Overstocked*, e.g. 'much overstocked, canopy dense, one gap, crowns symmetrical but small'.
3. *Understocked*, e.g. 'stocking 0·75, crowns well developed in large trees'.
4. *Rejected for Analysis*, e.g. 'irregular, overstocked in most places, gaps for 5 mean trees, crowns moderate'.

Occasionally the records make note of especially satisfactory plantations 'evidently well treated', 'well maintained', and so on. There were nine of these 'star' plots, to which special reference is made later.

It has to be borne in mind that the remarks were written by a number of different persons and that the personal factor comes into play.

Proceeding as described above, 308 larch plots were classified as follows:

Normally stocked	108 plots
Overstocked	67 „
Understocked	57 „
Rejected	76 „
Total . . .	308 „

The distribution as regards Quality Classes is shown in the Table I:

TABLE I. *Classification of Sample Plots by Quality Classes.*

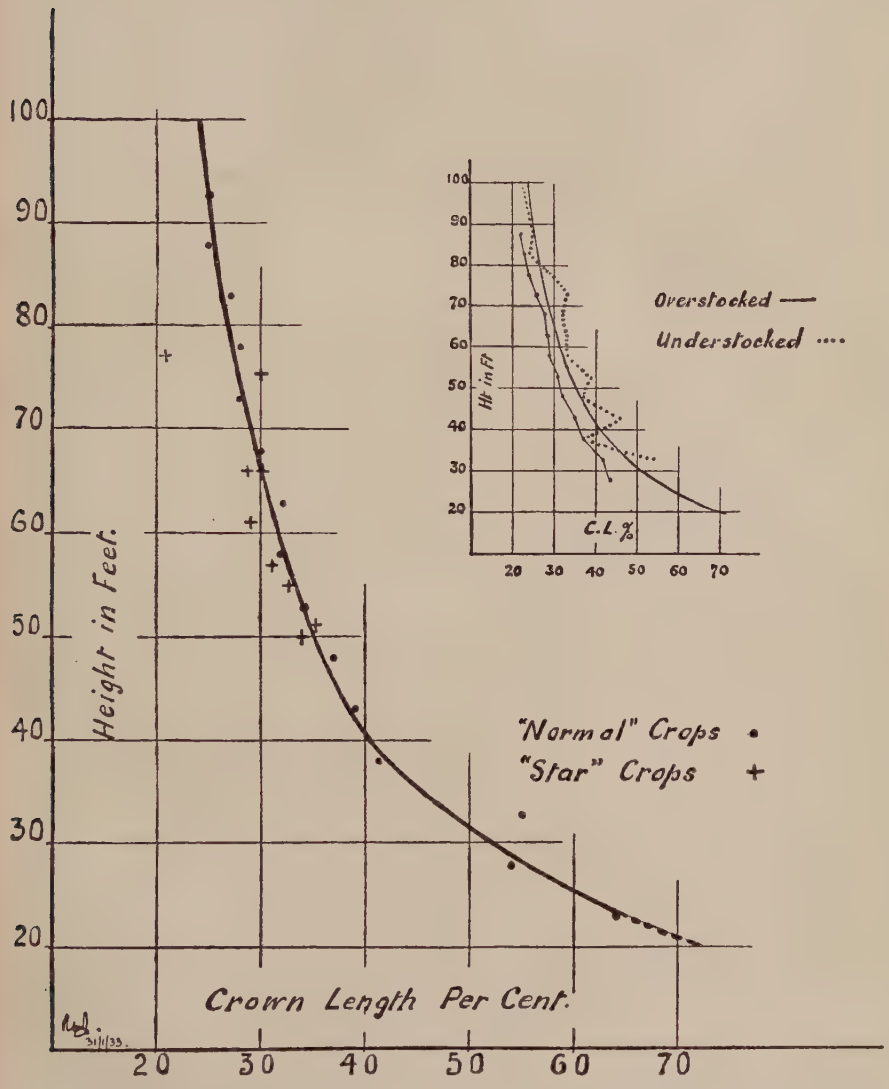
Quality Class.	*Normally stocked.*	*Over-stocked.*	*Under-stocked.*	*Rejected.*	*Total.*
I (80 feet at 50 years)	14	12	10	10	46
II (70 „ „ „)	43	27	17	28	115
III (60 „ „ „)	36	19	20	15	90
IV (50 „ „ „)	13	5	6	15	39
V (40 „ „ „)	2	4	4	8	18
	108	67	57	76	308

The high proportion of rejected plots in the lower quality classes is due to the fact that these plots were frequently growing under conditions (such as exposure) which had resulted in deformed crowns.

The normally stocked, overstocked, and understocked plots were next classified into 5 feet height classes and the average crown-lengths calculated for each height class. The results are given in Table II.

In the accompanying diagram the height classes were plotted against the crown-length for the 'normal' plots and the large curve drawn. The smaller

graph shows the overstocked and understocked plots treated in the same way and applied to the 'normal' curve. It would appear that the curve fits the points reasonably well, having regard to the fact that the 'normal' plots had



not necessarily been subjected to uniform thinning treatment; indeed it is highly probable that the majority of the plots, all of which were in private ownership, had been thinned irregularly with a tendency to keep the crop too dense. The 'star' plots also with one exception conform very closely to the curve. This exception is not important. It was the tallest of the 'star' plot and probably had not time to recover in appearance from early overstocking.

Table II.

Average Crown-lengths by Height Classes and Types of Plot

	Height Class (feet)																
	21–5	26–30	31–5	36–40	41–5	46–50	51–5	56–60	61–5	66–70	71–5	76–80	81–5	86–90	91–5	96–100	*Totals.*
							1. *Normally Stocked.*										
No. plots	2	2	1	4	9	14	13	16	9	15	7	7	4	4	1	..	108
Av. crown-length, per cent.	64	55	55	41½	39	37	34	32	32	30	28	28	27	25	25	..	—
							2. *Overstocked.*										
No. plots	..	1	3	7	8	10	6	12	4	4	3	4	2	3	..	..	67
Av. crown-length, per cent.	..	44	42	37	35	32	31	29	29	28	26	24	23	22	..	..	
							3. *Understocked.*										
No. plots	..	..	1	2	1	11	7	11	9	6	2	2	1	1	..	1	55
Av. crown-length, per cent.	..	..	54	37	46	37	39	33	33	32	33	29	24	25	..	23	
																Total plots . .	230

DISCUSSION OF THE RESULTS.

The lowest part of the curve is probably the least satisfactory and may need amendment when further data are available for young crops. Also it may well be found that with systematic thinnings the rest of the curve is thrown somewhat to the right, indicating longer crown-lengths for any given height. In any event, however, it is clear that a continuous reduction in the crown-length per cent. takes place as the height of the larch increases. The most striking feature about the height crown-length curve as now drawn is the very rapid reduction of the crown-length from the time canopy is formed until a height of 45 to 50 feet is reached; thereafter the reduction is much slower and the rate practically proportional to the increase in height. At 20 feet the crown-length per cent. is 72, at 50 feet it has fallen to 35, or approximately half, and at 100 feet to 24 per cent.

The statement is frequently made that one-third of the length of a larch should be kept 'feathered' with green branches. This proportion is not met with on the curve until a height of 56 feet is reached. For heights much below that figure the proportion is obviously far too low; for greater heights it can safely be less. Translated into actual lengths of green crown some rather striking figures emerge. At a height of 20 feet the crown is 14·4 feet long, at 100 feet it is only 24 feet, that is to say, in adding 80 feet to its stature the larch adds only about 10 feet in length to its living crown, the remaining 70 feet of course being at the end clear or covered with dead branches. On the other hand the living crown has developed greatly in spread and in leaf surface. With Quality Class I larch 100 feet high there should be about 150 larch per acre in a fully stocked wood, equivalent to an average horizontal crown-area of upwards 250 square feet. In a young stand of 20 feet high practically the whole of the original plants would be present; with 1,500 trees to the acre the average crown-area would be about 29 square feet.

The figures with regard to crown-length are stated in Table III, to which have been added certain data with regard to the rate of growth of Quality Class I larch, and the rate at which branches die off on the stem. It will be seen that whereas in early youth (between a height of 20 and 30 feet) the leading shoot is averaging 2·2 feet growth per annum, but the length of crown is increasing at the rate of only 0·2 feet, and the length of stem with dead branches consequently by 2·0 feet. At no time in the life of the crop does the living crown increase by more than 4 inches in a year (between 50 and 60 feet) and the addition then gradually falls to about one inch.

Any one who has had to do with larch knows what a tedious business it is to bring round an overcrowded crop towards normal stocking and appearance. The writer calls to mind an example in the Tintern Woods. The wood was about 45 years old and badly overstocked when first taken in hand about 20 years ago. Thinnings were made at frequent intervals (2 to 3 years), and although the appearance is now presentable, evidences of the early overstocking are still clearly visible. The crowns of these trees were probably 3 feet shorter than the normal at the beginning of treatment, and it is doubtful

whether the thinning has enabled them to catch up at the rate of more than 1 inch per annum. On that basis it would take 36 years for complete recovery.

The critical stage in the thinning of larch is between the heights of 30 feet or rather less, and 50 feet. Crops which are neglected not only develop whips and canker, but also recover extremely slowly when thinned.

The small graph is also interesting. It shows that for the plots classified as

TABLE III.

Height feet.	*Crown-length*		*Time to grow 00 ft.*	*Average length leading shoot.*	*Increase in Crown-length.*		*Increase per annum length of stem with dead branches.*
	per cent.	*feet.*			*Total.*	*per ann.*	
			years.	*feet.*	*feet.*	*feet.*	*feet.*
20	72	14·4	4+	2·2	1·1	0·2	2·0
30	52	15·5					
40	41	16·3	4+	2·1	0·8	0·2	1·9
50	35	17·6	5+	1·8	1·3	0·2	1·6
60	32	19·0	5+	1·5	1·4	0·3	1·2
70	29	20·3	8	1·25	1·3	0·2	1·0
80	27	21·5	10	1·0	1·2	0·1	0·9
90	25	22·7	12	0·8	1·2	0·1	0·7
100	24	24·0	16	0·6	1·3	0·1	0·5

'overstocked' the crown-length is consistently lower than the normal. The 'understocked' plots run very irregularly, and the explanation no doubt is that they had for the most part been overstocked at some time and had not recovered, at the time of measurement, from the last thinning.

So far as is known, the only writer who has made systematic use of the crown-length as an indicator of the density of the crop is Schiffel. His yield tables for spruce (3) are compiled for three densities of stocking, and the crown-lengths are stated for each density; for example, at about the middle quality class the crown-lengths per cent. at 55 feet are: Dense stands 46 per cent., Medium 49 per cent., Thin 51 per cent., as compared with normal larch 55 feet—33 per cent. Schiffel also makes some slight use of crown-length in his volume tables for larch (4), but he is there dealing with single trees and not crops. It is interesting nevertheless to note that his lowest crown-length for small trees (10 m.) is 47 per cent. and his highest 76 per cent.; for large trees (37 m.) the respective figures are 33 per cent. and 45 per cent.

CONCLUSION.

The general conclusion is that in the case of larch the crown-length is a valuable indicator of treatment (thinning) and that the subject is worth pursuing closely not only for that species but also for other conifers.

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(4) —— 'Form und Inhalt der Lärche.' *Mitt. aus dem forstl. Versuchsw. Österreichs*, xxxi.

MULTIPERFORATE PLATES IN VESSELS, WITH SPECIAL REFERENCE TO THE BIGNONIACEAE

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INTRODUCTION.

THE vessels of hardwoods possess many interesting features, but their most outstanding characteristic is the lack of a complete membrane enclosing each individual cell. The individual cells of a vessel—the vessel elements—are arranged one above the other in long vertical series, and communicate with each other through gaps, known as perforations, in their connecting walls. There may be only a single perforation in each joint wall, or there may be several; in the latter case the perforations are usually arranged in a characteristic pattern, as in the common scalariform type. The term perforation strictly refers only to an individual hole in a membrane, but it has also been used in the past for the whole group of perforations and membrane, as in 'a scalariform perforation'. In this instance it is obvious that it is the membrane separating the perforations which is ladder-like and not the perforations, and similar ambiguities are almost unavoidable whenever the term is used in this sense. To avoid these difficulties a committee of the International Association of Wood Anatomists, which has recently been considering terminology, has suggested 'perforation plate' to include both membrane and perforation; and the term multiperforate plate has been used in this paper to indicate any vessel membrane which includes more than one perforation, as for example a scalariform perforation plate. For the plate with only one perforation, 'simple perforation' has been retained, owing to its firm establishment, in preference to the more logical 'uniperforate plate', and may be regarded as an abbreviation for 'simple perforation plate'.

The two types of perforation plate mentioned above, the scalariform and simple, predominate in the Angiosperms, but there are also several other varieties which occur sporadically in a large number of genera. These are very varied in form and such classifications of them as have been put forward, for example by Solereder (17), Record (15), and F. B. H. Brown (2), are not entirely satisfactory.

Scalariform perforation plates are characteristic of the more primitive vessels, and are typically associated with long elements and oblique end-walls, while simple perforations are typical of advanced vessels with short elements and horizontal end-walls (Frost 7). Between these two extremes there are transitional stages in which both simple and scalariform plates occur side by side in the same wood.

In the less primitive of the woods with scalariform perforation plates, and in the transitional stages, it is not unusual to find an occasional more complex

plate in which the perforations are smaller and more numerous. These sometimes bear a distinct resemblance to the scalariform type, and on this account, and owing to their occurrence side by side with scalariform plates, are generally regarded merely as varieties of the scalariform.

Multiperforate plates occur also, though rarely, among woods with very advanced vessels, that is to say with very short vessel elements, horizontal end-walls, and normally simple perforations. Such perforation plates, bearing no relation to the scalariform type, are particularly common in the Bignoniaceae, where the end-walls of the vessels are so nearly horizontal that the multiperforate plates are best observed in transverse sections. The woods of this family are particularly interesting because the multiperforate plates exhibit a variety of form which does not appear to occur elsewhere. The most common form, and the only one which appears to have attracted any comment, differs considerably in appearance from those associated with scalariform plates. This form has been regarded as a distinct type under the term reticulate, a view which appears to be supported by the highly advanced character of the vessels in which it occurs; but a study of the other related forms which occur in this family has convinced the author that such a distinction is impracticable. Consideration of the manner in which these multiperforate plates develop also suggests that no clear distinction can be made between these forms which occur in very advanced woods and those which are associated with scalariform plates.

TYPES OF MULTIPERFORATE PLATE IN THE BIGNONIACEAE.

The type of perforation plate which originally attracted attention in the Nyctaginaceae and Boraginaceae, and which Thompson (19) called the *Cordia* type, occurs in several species of the Bignoniaceae. It consists of a thin membrane which is pierced by a large number of closely spaced angular perforations so that the membrane or perforation plate has the appearance of a fine net. This is illustrated below in Fig. 1 A.

There are several interesting features about these perforation plates which have already been pointed out by Thompson (19). Firstly, the plate is usually nearly horizontal and tends to sag in the middle (a tendency which renders focusing for photographic purposes extremely difficult), and secondly the individual perforations are very regular in size and arrangement, and never show any sign of coalescing to form larger perforations. The perforation plate itself is very thin, and Rodham (16) has commented on the difficulty of staining it with safranin. Deep staining with safranin produces a faint pink colour, but the membrane is not stained by phloroglucin, Haidenhaim's haematoxylin, ruthenium red, chrysoidin, aniline green, or Rubin S. Iodine and chlorophyll however stain it the same colour as the secondary wall.

The diameter of the perforations is very similar to that of the intervascular pits, a point which is illustrated by the small sample of pitting which is shown in Fig. 1 B.

In the Bignoniaceae there is also another form of multiperforate plate which in its extreme forms is in marked contrast to that described above. The

perforations are much larger—usually between two and five times the diameter of the intervascular pitting (see Fig. 2 A and B). They are usually rounded and more widely spaced, so that the netlike character of the *Cordia* form is absent and the plate has instead the appearance of having been irregularly pierced. The shape of the perforations, however, appears to depend primarily on the

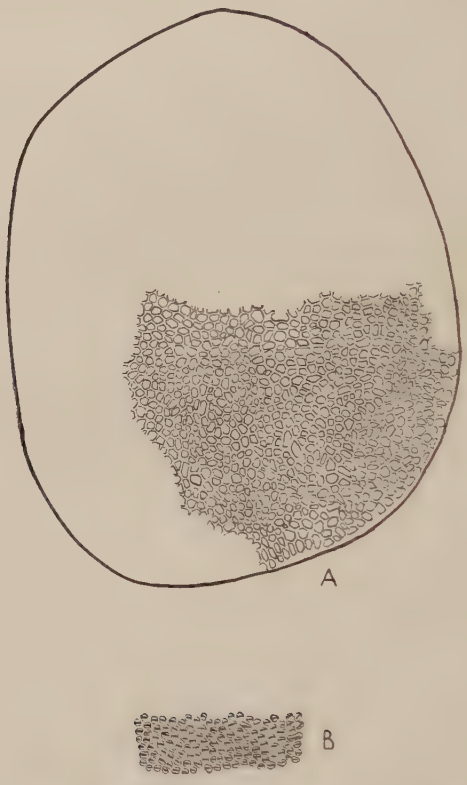

FIG. 1. *Stereospermum leonense* Sprague. (×170). A. Perforation Plate. B. Intervascular Pitting.

spacing of the perforations rather than on their size, and where the perforations are comparatively numerous, as in Fig. 2 A, there is sometimes a slight tendency towards angularity, and the membrane may appear netlike if slightly out of focus. This type of perforation plate will be referred to as the *Oroxylon* form to distinguish it from the finer *Cordia* form which has been described above. It is very common in *Oroxylon indicum* Vent., and occurs also in some species of *Dolichandrone*, particularly *D. platycalyx* Baker. In the latter species, both this and the *Cordia* form often occur together in the same specimen, and the coarser form exhibits considerable variety in the shape, size, and number of the perforations. Occasionally two or three smaller perforations are grouped together in such a way as to suggest a large perforation subdivided,

as in Fig. 3 c. The membrane is not always homogeneous, and various ridges and markings can sometimes be picked out by staining and the use of polarized light. Some of these perforation plates in *Dolichandrone* and all those of

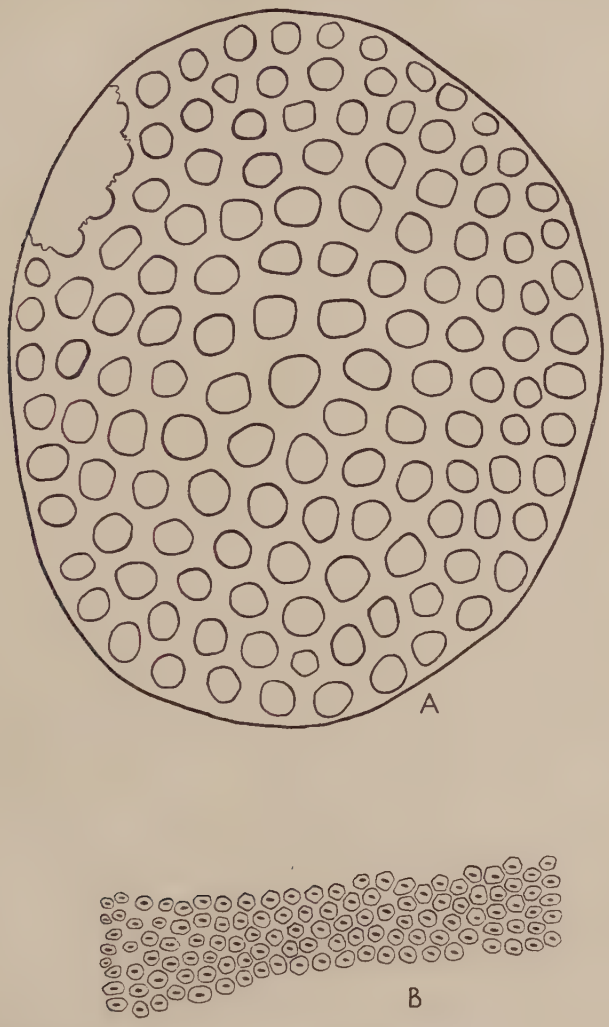

FIG. 2. *Oroxylon indicum* Vent. (× 180). A. Perforation Plate. B. Intervascular Pitting.

Oroxylon, however, stain in the same way as the secondary wall with safranin, phloroglucin, and aniline green.

A rather curious feature of some of the *Oroxylon* form plates in *Dolichandrone* is the presence of minute dots which appear to be perforations. These are often arranged in rows, as for example in Fig. 3 c, where they occur in pairs and look like footprints wandering about the membrane. Some further

examples of the varieties of multiperforate plate to be found in *Dolichandrone* are shown in Fig. 3 A, B, and C. These are all from the same specimen.

Both forms of multiperforate plate were observed in macerated material, and vessel elements which showed this feature were always multiperforate

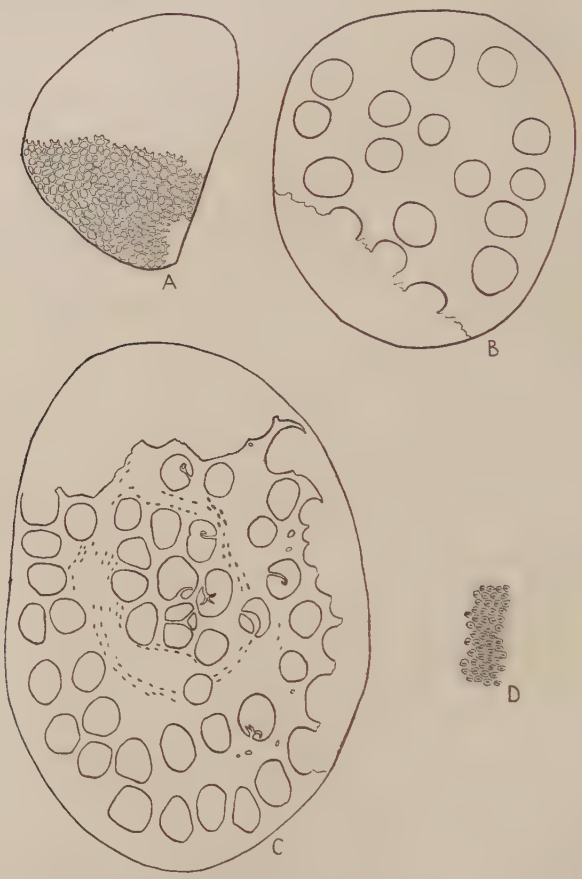

FIG. 3. *Dolichandrone platycalyx* Baker. A, B, and C. Perforation Plates. D. Intervascular Pitting. (A, B, and D, × 120, C × 140.)

at both ends. Such elements occurred singly, the multiperforate plate at either end abutting on to a simple perforation belonging to the next element, and multiperforate plates were not observed on both sides of a middle lamella. It was also noticed that both forms of multiperforate plate tended to be concave in the same direction at each end of the segment, as if in response to a pressure passing through the segment rather than to a force internal to the cell.

A very curious structure was observed in *Millingtonia hortensis* Linn.f., consisting of the *Cordia* form of plate overlaid with coarse anastomosing strands of thickening. The membrane of the netlike plate was unstained by

phloroglucin, but the coarse strands stained readily. The irregular strands of thickening, however, occurred also on the lateral walls, where they appeared to be additional to the secondary wall in a somewhat similar manner to spiral thickening. These elements are sporadic in occurrence but form a very striking feature in longitudinal sections and macerated material.

OCCURRENCE.

In 1879 Peterson (12) called attention to some curious sieve-like vessel perforations which he had observed, and at about the same time Dickson (5) described what appears to have been the same feature as occurring in *Bougainvillea glabra* and *Testudinaria elephantipes*. Dickson states quite definitely that the spaces of the mesh-work were not closed by a membrane in either case. Prael (14), in 1888, gave an account of this feature in a description of *Cordia myxa* (Boraginaceae), from which it is evident that he was unaware that it had been described before, and in the same year Peterson (12) called attention to his previous note. In 1923 Thompson (19) described these perforations in some detail under the term reticulate, and added *Bougainvillea speciosa*, *Vitex alata*, *Boerhaavia* sp., and *Cordia suaveolens* to the list of woods in which they had been observed.

The following list of species of Dicotyledons in which these perforation plates occur has been compiled from the observations of the author and from the literature.

Bignoniaceae (Personales):

Crescentia cujete Linn., *Dolichandrone platycalyx* Baker, *D. rheedii* Seem, *D. stipulata* Benth. and Hook. f., *Jacaranda copaia* D. Don, *Millingtonia hortensis* Linn. f., *Oroxylon indicum* Vent., *Pajanelia rheedii* Wight., *Stereospermum leonense* Sprague, *S. chelonoides* DC., *S. glandulosum* Miq., *Tabebuia glomerata* Urb., and *Tecoma radicans* Juss.

Boraginaceae (Boraginales):

Cordia myxa Linn., *C. suaveolens* Blume, and probably other species.

Nyctaginaceae:

Boerhaavia sp., *Bougainvillea speciosa* Schnizl., *B. glabra* Choisy, and *B. spectabilis* Willd.

Verbenaceae (Lamiales):

Vitex alata Roxb.

Three of these families belong to very closely allied groups of the Sympetalae, the Lamiales, Personales, and the Boraginales. The position of the fourth, the Nyctaginaceae, appears to be uncertain. It is sometimes placed in the Apetalae, but it appears possible that it may be more nearly allied to some of the Sympetalae.

DISCUSSION.

Multiperforate plates of a rather similar nature to those which have been described above occur quite commonly in woods which have scalariform plates. Some examples of these are given in Plates I and II, Figs. 5–11. Their

association with scalariform plates and the fact that they frequently have at least a suggestion of scalariform pattern tend to mark these forms as distinct from the *Cordia* and *Oroxylon* forms. One of the most striking features about the latter is the fact that they occur in such highly specialized vessels, as indicated by the extremely short elements, horizontal end-walls, and normally simple perforations. Scalariform plates, on the other hand, are typical of primitive vessels (Frost 7), and there appears to be a gap between these two groups of complex multiperforate plates suggestive of a separate line of development.[1]

In order to obtain some evidence on this point a search was made through over 130 genera with scalariform plates, and a record was made both of the types of perforation plate and the type of intervascular pitting with which each was associated. This fully confirmed the connexion between type of pitting and the occurrence of scalariform or simple perforation plates which was expounded by Frost (8), and a similar connexion was found to exist in regard to the more complex plates. The pattern of the latter was found to be closely related to that of the intervascular pits, and it is suggested that these complex plates, which are of very sporadic occurrence in the individual, are in the nature of an aberration which takes the form of a tendency to reproduce on the end-walls the pattern of the intervascular pitting of the lateral walls. It was found that with each type of pitting the form taken by the aberration tended to differ slightly. Thus with transitional pitting the perforations were mostly elongated horizontally, as in Figs. 6, 7, and 9, though isodiametric perforations did occur in some instances. Conversely the rounded pit-like forms, as in Fig. 11, were not observed with transitional pitting, occurred occasionally with opposite, and were most common with alternate pitting. The irregular forms of perforation plate which occur in perforated ray cells (4) furnish another example of the effect of pitting on the form of the perforations. It is, however, difficult to demonstrate any exact correlation with pitting because the aberration is sometimes not carried very far, so that each perforation may correspond in area to more than one pit. Also the intervascular pitting is not always constant in form, particularly when it is intermediate between two types, so that unless the intervascular pitting and the perforation plate are visible in the same element, it is impossible to be certain with which type of pitting the perforation plate should be correlated.

A point of considerable interest in this connexion is the fact that no complex forms of plate were observed with scalariform intervascular pitting. This was to be expected if the above explanation of the aberration is correct, as scalariform pitting could only give rise to scalariform perforation plates, but it is difficult to explain if these complex forms are regarded merely as varieties of scalariform plates.

[1] The netlike perforation plates which sometimes occur in the Compositae, as figured by Tangl (18), are not included in the following discussion, because they appear to be essentially scalariform plates, the netlike effect being produced by the different orientation of two scalariform plates on opposite sites of a common end wall.

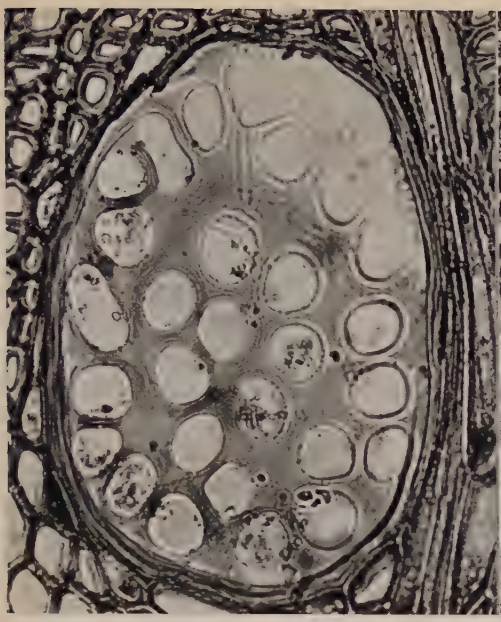

FIG. 4. *Dolichandrone platycalyx* Baker. Bignoniaceae. (× 400)

FIG. 5. *Ctenolophon englerianus* Mildbr. Linaceae (?). (× 400)

FIG. 6. *Eupomatia laurina* R. Br. Anonaceae. (× 400)

FIG. 7. *Adinandra dumosa* Jack. Theaceae. (× 400)

Figs. 4 and 5. Similar perforation plates from widely separated woods. Fig. 4 the *Oroxylon* form from a very advanced wood, and Fig. 5 from a wood with simple and scalariform plates.

Figs. 6 and 7. Forms of perforation plate associated with transitional intervascular pitting.

PLATE I

This explanation of the origin of the complex forms which occur in association with scalariform plates is equally applicable to the *Cordia* and *Oroxylon* forms. The similarity in size and shape between the perforations and the intervascular pits is very striking in the *Cordia* form, and, if we regard this form as the ultimate result of this tendency in these very advanced woods, the *Oroxylon* form may be taken as the intermediate stage between the *Cordia* form and the simple perforation. Some confirmation of this is to be found in the occasional presence of what appear to be subdivisions of the larger perforations in the *Oroxylon* form. Similar intermediate forms occur in association with scalariform plates, the individual perforations being intermediate in size between those of the scalariform plates and the intervascular pits.

It would, therefore, appear justifiable to regard all these varieties of multiperforate plate, other than the scalariform, as essentially the same feature. The exact shape and size of the perforations seems to depend on two factors. Firstly the extent to which the aberration is carried, as for example the formation of both the *Cordia* and *Oroxylon* forms from the same type of pitting. Secondly the type of pitting, alternate pitting, for example, giving rise to the plate shown in Fig. 1, and transitional pitting to the plate shown in Fig. 7. The frequent horizontal elongation of the perforations in the less advanced woods, which suggests derivation from a scalariform plate, is more probably due to the character of the pitting, which in the majority of cases is transitional or opposite.

The peculiarity of the *Cordia* and *Oroxylon* forms is, therefore, not the shape and size of the perforations, but the fact that they occur in such highly specialized vessels. The association of the other forms with scalariform plates creates the impression that these are limited to primitive vessels, and there appears therefore to be a distinct gap between these and the highly specialized vessels in which the *Cordia* and *Oroxylon* forms occur. But the former are not really limited to primitive vessels and the gap is not a very wide one. As will be seen in the following table, there is as high a percentage of genera with complex forms of plate in the group with alternate pitting, which is the most advanced type Frost (8) and Brown (3), as there is with transitional or opposite pitting. It is only with the most primitive type of pitting, the scalariform, that there are no complex forms. In many of the genera with alternate pitting the perforation plates are predominantly simple, yet there appears to be no decrease in the proportion with complex forms.

TABLE I

	No. of genera with scalariform or simple and scalariform plates.	*Percentage of genera with complex plates.*
Scalariform pitting	16	0
Transitional pitting	30	53
Opposite pitting	48	40
Alternate pitting	37	51

The classification of all these complex forms of perforation plate depends largely on the answers to two questions: firstly whether the *Cordia* and *Oroxylon* forms are sufficiently distinct from the others in origin to warrant their separation as a distinct type, and secondly whether such a distinction is practicable.

From what has already been stated, it is clear that some of the forms which have been grouped as typical of primitive vessels actually occur in comparatively advanced vessels, that is to say in vessels with predominantly simple perforations and alternate pitting, and the difference in degree of specialization between these and the vessels of the Bignoniaceae is not so very marked. The explanation of the differences in the character of the plates would appear to lie not in any difference in mode of origin but in the character of the vessels in which they occur. Thus the horizontal position of the membrane in the *Cordia* and *Oroxylon* forms can be attributed to the occurrence of these forms in vessels which normally have horizontal end walls. Similarly the small size and angularity of the perforations in the *Cordia* form appear to be directly related to the small hexagonal pits on the side walls. Even the unusual reaction to stains does not form a definite line of division, as the membrane of the *Oroxylon* form often stains in an exactly similar way to the secondary wall.

There does not appear, therefore, to be any necessity for separating the *Cordia* and *Oroxylon* forms from the rest on evolutionary grounds, nor is such a distinction free of practical difficulties. The *Cordia* form can and has been so distinguished, as for example by Thompson (19) under the terms reticulate, and 'reticulated-scalariform' has been suggested for the forms associated with scalariform plates. But the fitting of the *Oroxylon* form into such a classification presents considerable difficulties. It is so closely associated with the *Cordia* form that it would be undesirable to segregate one without the other, but it is extremely difficult to frame any definition which would cover both forms and at the same time serve to separate them from the rest. In any case it could hardly be included under a term meaning net-like.

The difference between the *Cordia* and *Oroxylon* forms suggests an alternative line of division which might be applied throughout, namely a distinction between those forms in which the membrane is net-like and those in which it has the appearance of a pierced plate, for which the terms reticulate and foraminate are appropriate. This difference in appearance depends partly on the width of the intervening membrane relative to the diameter of the perforations, and partly on the roundness or angularity of the perforations. The latter probably provides the most serviceable means of definition, and used in this sense 'reticulate' can be applied to the plates with angular perforations shown in Figs. 1, 9, and 10, and 'foraminate' to those with round perforations in Figs. 4–8, and 11. Such a distinction is easy to apply and would lend itself to further subdivision if it were so desired.

In conclusion I wish to express my thanks to Miss M. M. Chattaway, Mr. B. J. Rendle, and Mr. S. H. Clarke for helpful criticism during this investiga-

tion, and to Mr. A. L. Clinkard for his assistance in producing the photomicrographs.

SUMMARY.

1. The multiperforate plates occurring in woods of the Bignoniaceae are described and two forms are distinguished.

2. These are considered in relation to the complex forms which occur sporadically in association with scalariform plates, and it is suggested that both are similar in origin and are closely connected with the intervascular pitting on the lateral walls.

3. The distinction between the forms of perforation plate in the Bignoniaceae and those associated with scalariform plates is not clearly defined and their separation for purposes of classification is regarded as impracticable. An alternative classification is suggested, based on the reticulate or foraminate character of the perforation plates.

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ON ESTIMATING THE MECHANICAL STRENGTH OF THE WOOD OF ASH

(*Fraxinus excelsior* L.)

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INTRODUCTION.

THE mechanical properties of a piece of wood may be regarded as functions of the amount of wood substance present, the constitution of the wood substance, and the manner in which it is distributed (1). Ideally, each of these factors should be considered in estimating the strength of wood, and while it has come to be generally accepted that the specific gravity of wood is the best single feature to use as an index of its mechanical strength, it is clearly an expression of only one of the three basic factors mentioned, namely, the amount of wood substance present. So far, sufficient work has not been done to enable the chemical constitution of the wood to be taken into account in estimating mechanical strength, and but little consideration has been given to the distribution of the wood substance.

In a previous investigation (1) an attempt was made to find a structural explanation for variations in mechanical strength in elm, and recently a similar study of the wood of ash has been started. The aim of the investigation is to indicate the structural features of a normal sample of ash, and the structural range that may be associated with normal mechanical strength, and to formulate criteria by which abnormal values of any feature may be recognized and their probable influence on mechanical strength estimated. This involves a study of variations in the distribution of the wood substance.

Since material from seven trees of only two localities has so far been examined in detail, the results cannot be regarded as conclusive, but they suggest a method for obtaining a more accurate estimate of the mechanical strength of ash wood than that offered by previous methods. The object of the present paper is to describe these results only in so far as they reveal the possibility of taking into consideration the distribution of wood substance; a full account of the investigation must be left until a later date when more material has been examined.

MATERIAL AND METHODS.

The observations were carried out on 300 bobbin-shaped mechanical test specimens so designed that it was possible to examine the complete cross-section of the zone of failure. The investigation included observations on the specific gravity,[1] the width of the annual rings, the percentage of summerwood in the test pieces, and the percentage of cell-wall substance in the zones of

[1] Throughout this paper, specific gravity refers to the ratio $\frac{\text{oven-dry weight}}{\text{saturated volume}}$.

summerwood fibres. The mechanical property considered was the maximum crushing strength in compression parallel to the grain, the specimens being tested in the green condition.

The interrelation of the above features was examined by the statistical methods described by Fisher (2, chap. VI), the results being expressed as correlation coefficients. It may be stated that a correlation coefficient is a number expressing the degree of correlation between two variates, as, for example, weight and volume, or specific gravity and strength. A correlation coefficient of +1 indicates a direct linear relation, a coefficient of −1 indicates an inverse linear relation, while one of 0·0 indicates absence of relations between the variates. In the case in question, the relations were not truly linear, but they were approximately so within the ranges under consideration. It is frequently the case that more than two interrelated variates are introduced, and it is neither possible to control any of them, nor practicable to make a sufficiently large number of observations in which all but two variates are constant. Under these circumstances it is possible to calculate partial correlation coefficients which yield estimates of the correlation of given pairs of variates in a population selected so that other variates are constant. For instance, taking into consideration all the material examined in the present investigation, the correlation coefficient between specific gravity and strength was +0·56 (Table I); if we could obtain a sufficiently large number of specimens of the same ring-width, and with the same proportion of summerwood in the annual rings, a somewhat closer relation would exist between specific gravity and strength, and a correlation coefficient of +0·61 might be expected. Thus, the relation between, say, specific gravity and strength is masked by the behaviour of other variates, such as the proportion of summerwood in the annual ring.

RESULTS AND DISCUSSION.

A summary of the correlation coefficients and partial correlation coefficients is given in Table I.

In this table only four features are considered, namely, strength, specific gravity, ring-width, and the percentage of summerwood in the test pieces. Each partial correlation coefficient represents the correlation of a pair of

TABLE I.—*Correlation of structural features and strength.*

Features.	*Correlation coefficients* ($N = 300$)	*Partial correlation coefficients.*
Specific gravity and strength . .	+0·56	+0·61
„ „ „ ring width .	+0·09	−0·15
„ „ „ summerwood* .	+0·39	+0·47
Ring-width and strength . .	−0·21	−0·09
„ „ „ summerwood* .	+0·69	+0·68
Strength and summerwood* . .	−0·05	−0·19

* The summerwood was measured as a percentage of the complete cross-section of the test-piece.

variates when the other two are constant. The partial correlation coefficient of −0·09 indicates that the relation between ring-width and strength is not close, and it is suggested that the apparent inverse relation indicated by the correlation coefficient of −0·21 is probably a reflection of the relation between ring-width and percentage of summerwood in the ring (partial correlation +0·68), for at constant specific gravity, strength is inversely related to the percentage of summerwood in the sample (partial correlation coefficient −0·19). In other words, it would appear that a consideration of growth-rate is not of fundamental importance in estimating the strength of ash.

The significance of fibre-wall thickness in determining the mechanical strength of ash is illustrated in Plate III. In Figs. 3 to 5 the microscopic structure of the summerwood fibres of strong, average, and weak samples are compared; Fig. 6 shows the fibres of an exceptionally weak piece of ash from a broken tennis racket. In order to assess the importance of fibre-wall thickness, a number of samples was selected to cover the full range of specific gravity, and the percentage of cell-wall substance in the zone of summerwood fibres was estimated by means of a Shand's Recording Micrometer. This percentage was multiplied by the percentage of summerwood in the test piece, so that, neglecting the rays and the summerwood vessels, the resulting figure was an estimate of the summerwood fibre walls as a percentage of the test piece. A close relation was shown to exist between this figure and the specific gravity (correlation coefficient +0·91).

The significance of this observation lies in the fact that it opens a way for the consideration of the distribution of wood substance. For any given percentage of summerwood and ring-width, an increase in specific gravity would probably be due largely to increased thickness of the fibre walls, and would be accompanied by an increase in strength.

The first step in tracing these relations was to arrange the data according to the percentage of summerwood in the test pieces in groups 40–50, 50–60, 60–70, and 70–80 per cent. For each range of summerwood the regression of strength on specific gravity was plotted. The curves were fitted to the data by the usual formula ($y = r\frac{\sigma_y}{\sigma_x}x$), and are shown in Fig. 1, from which individual points are omitted to avoid confusion. It will be observed that for any given value of specific gravity, the higher the percentage of summerwood, the lower is the strength, or, for any given strength value, the higher the percentage of summerwood, the higher is the specific gravity.

The simplest way of applying these results in practice is to interpolate curves for intermediate percentages of summerwood. The slope of the curve for 50–60 per cent. of summerwood is slightly less than that of the remainder; in the following approximations it was regarded as falling between the curves of 40–50 and 60–70 per cent. It will be observed that the curves for 40–50, 60–70, and 70–80 per cent. of summerwood are roughly parallel to each other. Of these the curve for 60–70 per cent. is based on the largest number of samples and is also a convenient basis, since the mean percentage of summerwood in all

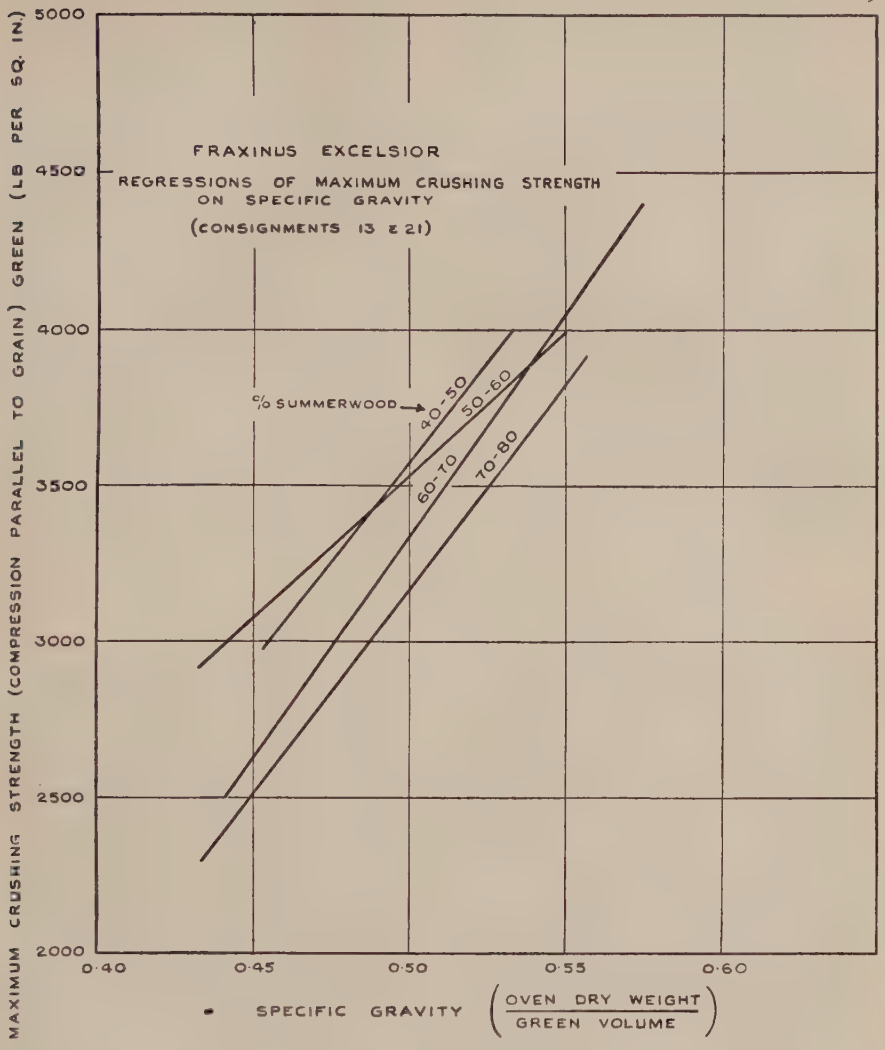

FIG. 1

the samples tested was 65·7 per cent. This curve was, therefore, repeated (Fig. 2), and on each side of it additional curves were drawn to represent other percentages of summerwood. The distances between the curves were obtained from Fig. 1, by dividers, and are only approximate. On applying the method to the material used in the present investigation it was observed that the estimated strength agreed with the tested strength as follows:

within ±200 lb. per sq. in. in 35 per cent. of the samples.
" ±300 " " " " 50 " " "
" ±400 " " " " 63 " " "
" ±600 " " " " 82 " " "

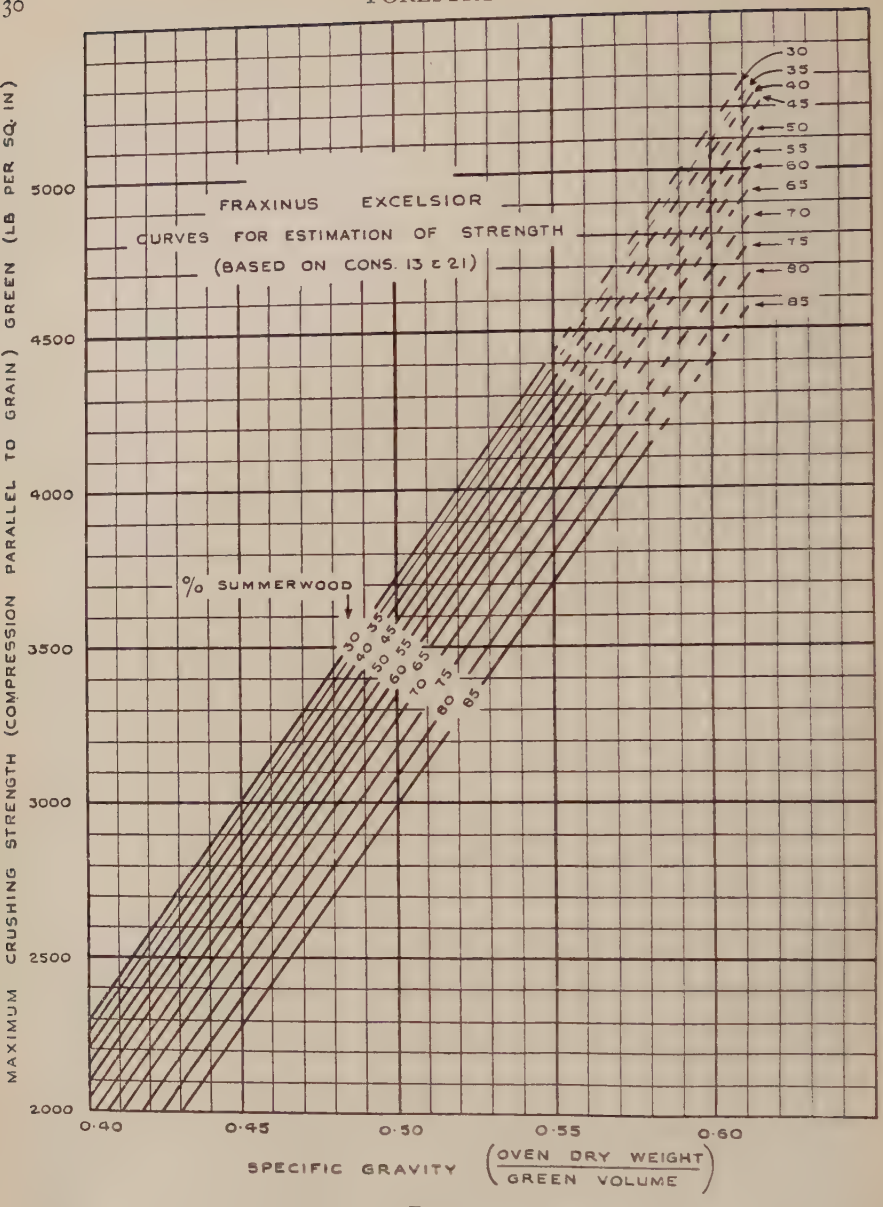

FIG. 2

SUMMARY.

(1) Examination of the anatomical structure and specific gravity of English ash in relation to the mechanical properties of the wood led to the following conclusions:

(*a*) For any given specific gravity an increase in the proportion of summerwood in the annual ring is accompanied by a decrease in mechanical

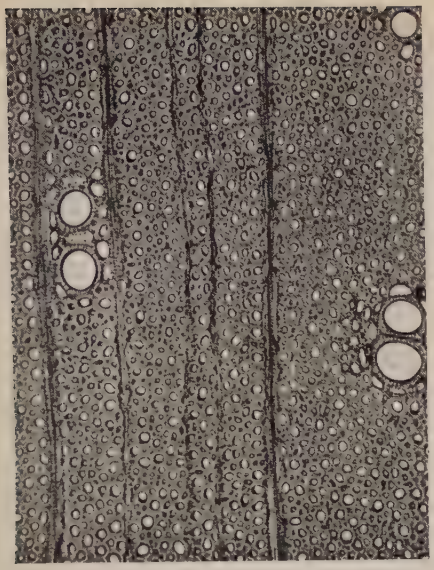

FIG. 3

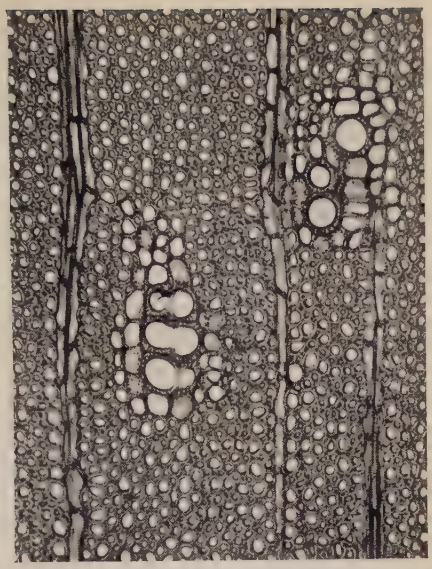

FIG. 4

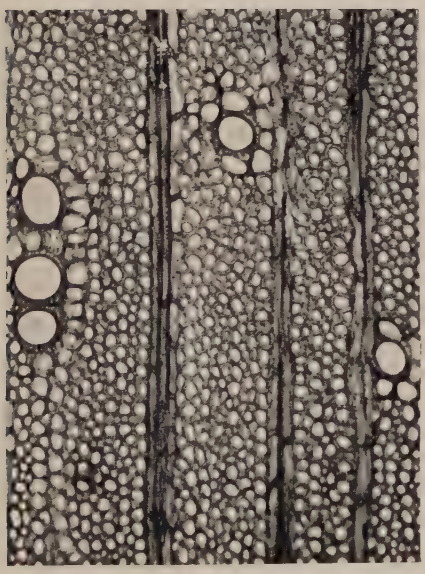

FIG. 5

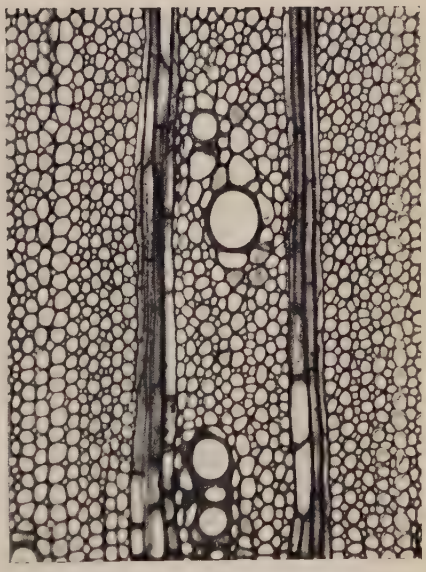

FIG. 6

Fraxinus excelsior L. (Ash)

Photomicrographs of transverse sections (magnification × 100), showing variations in thickness of fibre walls

PLATE III

strength, which is ascribed to a decrease in the thickness of the walls of the summerwood fibres.

(*b*) For any given proportion of summerwood in the annual ring, an increase in specific gravity is accompanied by an increase in mechanical strength, due to an increase in the thickness of the fibre walls.

(2) These relations were employed to derive a method of estimating the mechanical strength by considering both the amount of wood substance present and its distribution as measured by the specific gravity and the percentage of summerwood.

ACKNOWLEDGEMENTS.

I am indebted to Sir Ralph Pearson, C.I.E., LL.D., F.L.S., Director of Forest Products Research, for permission to publish this article; and to Dr. E. S. Pearson, of University College, London, for advice on the statistical treatment of the data, and for reading through the manuscript.

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EXPLANATION OF PLATE III

(Photomicrographs of transverse sections, magnification × 100.)

FIG. 3. Fibres of strongest sample of consignment.
Specific gravity: 0·58.
Maximum crushing strength: 5,300 lb. per sq. in.

FIG. 4. Fibres of an average sample.

FIG. 5. Fibres of weakest sample of consignment.
Specific gravity: 0·46.
Maximum crushing strength: 2,270 lb. per sq. in.

FIG. 6. Fibres of a sample from a tennis racket broken in play.

THE FORM OF THE STEM IN CONIFEROUS TREES[1]

(*Continued*)

BY JAMES MACDONALD

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Scots Pine (*Pinus silvestris* L.). The investigation of the form of the stem in Scots pine was based, after the rejection of irregular and doubtful measurements, on data from 367 trees. Those trees were measured in different parts of Great Britain, and they make up a representative sample of the younger and middle-aged stands in the country. No measurements were obtained of large, mature trees because this type of material, to a great extent, disappeared during the War, and there has been little felling since then in such stands as remain.

The data proved to be rather irregular, and root swelling was present in most of the trees. This root swelling, however, was less pronounced than in some of the other species, and after it had been eliminated the following series were obtained for the various form classes (Table XVI).

TABLE XVI. *Scots Pine.*

Form-Class.	*No. of trees.*	*Girth as a percentage of breast-height girth at*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
		per cent. of the stem above breast height.								
60	4	92·1	83·8	76·4	69·8	60·7	52·9	40·0	29·2	17·8
65	42	94·8	87·9	81·6	74·5	66·3	57·0	45·2	32·4	16·8
70	168	95·9	90·4	84·8	78·3	70·7	61·7	50·7	35·3	18·5
75	135	96·7	91·9	85·9	81·6	74·8	63·8	54·7	43·4	21·9
80	17	97·6	93·8	89·9	85·4	79·4	71·4	60·2	43·1	23·4
85	1	97·7	97·0	91·6	91·6	86·2	80·9	70·1	51·2	27·0

Most of the data is concentrated in two form-classes, viz. 70 and 75, although 65 is moderately well represented. Form-classes 60, 80, and 85 are so poorly represented that they must meanwhile be ignored.

The actual series for form-classes 65, 70, and 75 have been compared with the calculated values given by Höjer's and Behre's equations and the differences are shown below.

The differences given in Table XVII are interesting as they show that the form of the stem in Scots pine, when compared with the theoretical curves, is considerably fuller in the upper part than that of either the larch or the spruce. There are some irregularities in the lower part of the stem.

There was much variation in the material collected in the forest, and groups of trees from one plot did not correspond well with groups from other plots,

[1] Continued from *Forestry*, vi, No. 2, pp. 143–53.

although the form-class was the same. It is not clear why this should be so. It is possible, however, that the grouping together of material from widely

TABLE XVII. *Scots Pine.*

Form-class.	*Theoretical Curve.*	*Difference between actual and theoretical values at percentage heights.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
65	Höjer-Jonson .	+0·6	+0·1	+0·7	+1·1	+1·3	+1·4	+0·2	−0·3	−1·2
	„ (S. pine) .	+0·5	−0·1	+0·5	+1·0	+1·3	+1·6	+0·9	+1·3	+1·8
	Behre . .	+0·4	−0·2	+0·4	+0·9	+1·3	+1·7	+0·9	+0·5	−0·3
70	Höjer-Jonson .	+0·7	+0·5	+0·8	+0·8	+0·7	+0·3	−0·6	−3·5	−4·2
	„ (S. pine) .	+0·6	+0·4	+0·7	+0·8	+0·7	+0·6	+0·1	−1·9	−0·9
	Behre . .	+0·4	+0·1	+0·3	+0·5	+0·7	+0·8	+0·7	−1·5	−2·1
75	Höjer-Jonson .	+0·6	+0·2	−1·0	+0·2	−0·2	−3·7	−3·5	−2·9	−7·4
	„ (S. pine) .	+0·5	..	−1·1	+0·1	−0·2	−3·5	−2·9	−1·4	−3·7
	Behre . .	+0·3	−0·4	−1·6	−0·2	−0·2	−3·0	−1·6	+0·5	−3·1

differing sites, from the south of England and from the north of Scotland, from light sandy soils and from heavy clays, may have been responsible. It is well known, for example, that the growth of Scots pine on a heavy clay soil is in character entirely different from its growth on a light sand; although the actual rates of growth may be identical, the heavy soil gives a coarser and more heavily branched tree with an irregular stem and correspondingly irregular form quotient values. This would prove true particularly with young trees. It is unfortunate in this connexion that we have no material from old and mature stands for comparison. Had such data been available it would have been possible to determine whether the irregularities in stem form are characteristic of Scots pine in Great Britain or whether, as is most likely, they are associated with the immaturity of the material with which we have had to deal, and with the variations in site.

Of the three curves, the original, unmodified Höjer-Jonson curve gives the least satisfactory agreement.

Fig. 3 has been prepared to show the conformity of Scots pine in form-classes 65, 70, and 75 to Behre's theoretical curves.

Corsican Pine (*Pinus nigra* var. *Calabrica* Schneid). In this species an examination of material collected almost entirely in the south and south-west of England has yielded an interesting series of form-class values based, after the elimination of doubtful measurements, on data from 152 trees. The form-classes which are represented range from 55 to 80, but the greater part of the material is found in form-classes 65, 70, and 75. It is, however, more evenly distributed among the form classes than the material representative of Scots pine. The data for Corsican pine have been collected from young plantations, of which only two are more than 40 years old.

Root swelling was present and affected the breast-height measurement in 55 per cent. of the trees, a figure which is lower than the corresponding per-

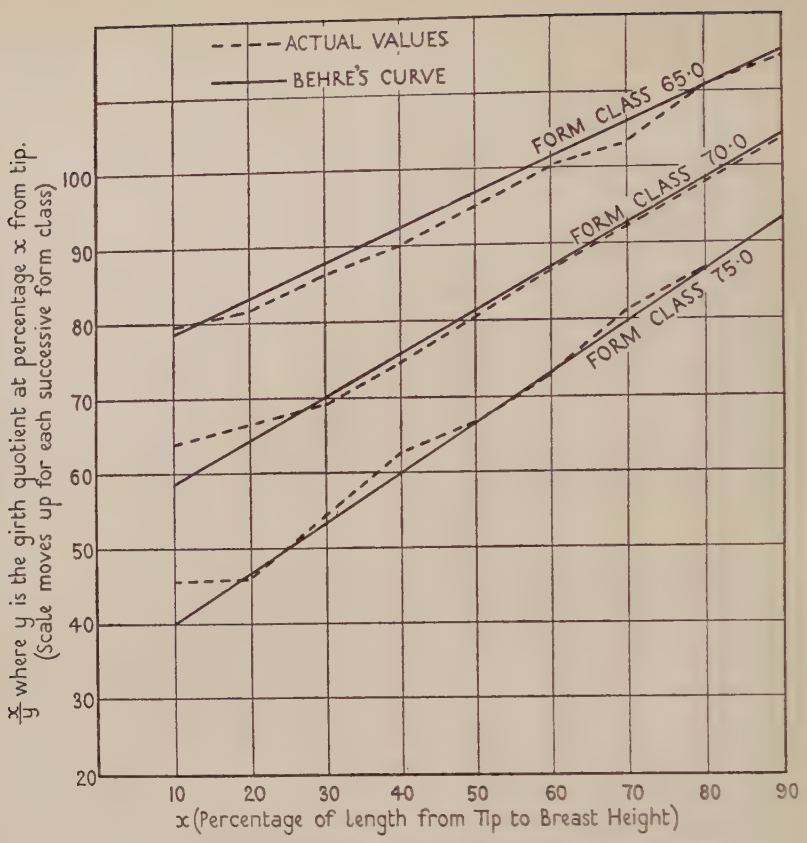

FIG. 3. To show the conformity of Scots Pine to Behre's Curves.

centages for other species. Root swelling seems definitely to be less strongly marked in young trees of Corsican pine than in similar trees of other species.

Where it occurred it was eliminated in the usual way and the form quotients calculated. The series of values that was obtained is shown in Table XVIII.

TABLE XVIII. *Corsican Pine.*

Form-class.	*No. of trees.*	*Girth as a percentage of breast-height girth at per cent. of the stem above breast height.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
55	2	90·2	81·0	70·9	62·5	54·7	46·2	38·4	30·0	19·2
60	5	92·9	84·5	76·6	69·0	60·4	51·6	42·7	29·5	18·5
65	30	95·4	88·7	81·9	74·3	65·8	56·6	45·7	33·6	20·2
70	54	96·0	90·8	84·8	78·2	69·9	60·3	49·8	36·8	20·8
75	44	97·0	92·9	88·5	82·1	74·5	65·4	53·7	39·1	22·8
80	17	97·8	94·9	90·8	86·7	79·4	70·7	58·9	44·0	22·3

On comparing the values in the best-represented form classes (65, 70, 75) with the values obtained from (1) the Höjer-Jonson equation, (2) the Höjer-

Jonson equation for Scots pine, and (3) Behre's equation, we obtain the following differences (Table XIX).

TABLE XIX. *Corsican Pine.*

Form-class.	*Theoretical Curve.*	*Difference between actual and theoretical values at percentage heights.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
65	Höjer-Jonson .	+1·2	+0·9	+1·0	+0·9	+0·8	+1·0	+0·7	+0·9	+0·5
	„ (S. pine) .	+1·1	+0·7	+0·8	+0·8	+0·8	+1·2	+1·4	+2·5	+3·5
	Behre . .	+1·0	+0·6	+0·7	+0·7	+0·8	+1·3	+1·4	+1·9	+1·4
70	Höjer-Jonson .	+0·8	+0·9	+0·8	+0·7	−0·1	−1·1	−1·5	−2·0	−1·9
	„ (S. pine) .	+0·7	+0·8	+0·7	+0·7	−0·1	−0·8	−0·8	−0·4	+1·4
	Behre . .	+0·5	+0·5	+0·3	+0·4	−0·1	−0·6	−0·2	..	+0·2
75	Höjer-Jonson .	+0·9	+1·2	+1·6	+0·7	−0·5	−2·1	−4·5	−7·2	−6·5
	„ (S. pine) .	+0·8	+1·0	+1·5	+0·6	−0·5	−1·9	−3·9	−5·7	−2·8
	Behre . .	+0·6	+0·6	+1·0	+0·3	−0·5	−1·3	−2·6	−3·8	−2·2

The figures for form-classes 70 and 75 agree with the general trend of our data in that they show, when compared with the theoretical curves, an excess in the lower part of the stem and a deficiency in the upper portion, and, as one would expect, this tendency is more strongly marked in the higher form-class. In form-class 65, on the other hand, there is an excess at each point of measurement and there is no indication of any deficiency near the tip of the tree.

It is interesting to notice that in form-classes 70 and 75 the deficiency at the 80 per cent. point of measurement is greater than at the point immediately above. This contrasts with the conditions in the spruces and larches, where the deficiency increased on going upwards towards the tip.

Of the three curves, Behre's gives the best fit for form-classes 70 and 75 while the Höjer-Jonson curves for Scots pine are preferable to the other curves based on Höjer's equation. In form-class 65 there seems to be little to choose between the curves, but the Höjer-Jonson curve for Scots pine gives a less satisfactory agreement in the upper part of the stem. Fig. 4 shows the conformity of this species to Behre's curve.

Weymouth Pine (*Pinus Strobus* L.). A few trees of this species were measured in two sample plots, one in Alice Holt Forest, Hampshire, and the other at Dunach, Argyllshire. Only 19 trees were employed and the results, therefore,

TABLE XX. *Weymouth Pine.*

Form-class.	*No. of trees.*	*Girth as a percentage of breast-height girth at per cent. of the stem above breast height.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
55	1	94·0	84·6	75·2	65·8	54·1	47·0	32·9	23·5	11·8
60	2	96·3	89·9	84·0	68·9	61·3	51·4	39·2	26·6	11·4
65	8	96·0	89·8	83·4	73·4	64·1	52·1	40·1	24·8	11·2
70	6	97·0	90·9	85·5	77·8	70·5	59·1	45·2	30·7	15·4
75	2	97·4	92·3	90·2	86·3	76·6	63·8	51·2	34·3	15·4

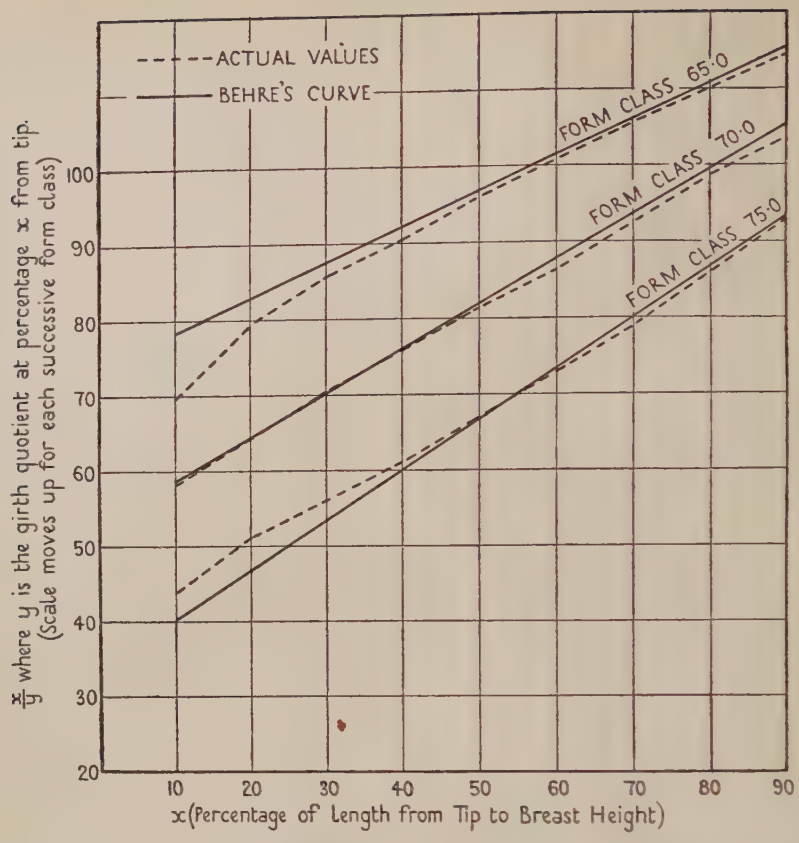

FIG. 4. To show the conformity of Corsican Pine to Behre's Curves.

though interesting, cannot be regarded as of any great importance. The figures, however, are given as an indication of the form of this species in plantations between 20 and 30 years of age.

Comparing the data for form-classes 65 and 70 with the theoretical values from Höjer's and Behre's equations, we obtain the following differences (Table XXI):

TABLE XXI. *Weymouth Pine.*

Form-class.	*Theoretical Curve.*	*Difference between actual and theoretical values at percentage heights.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
65	Höjer-Jonson (Scots pine)	+1·7	+1·8	+2·3	−0·1	−0·9	−3·3	−4·2	−6·3	−3·8
	Behre . .	+1·6	+1·7	+2·2	−0·2	−0·9	−3·2	−4·2	−6·9	−5·9
70	Höjer-Jonson (Scots pine)	+1·7	+0·9	+1·4	+0·3	+0·5	−2·0	−5·4	−6·5	−4·0
	Behre . .	+1·5	+0·6	+0·6	..	+0·5	−1·8	−4·8	−6·1	−5·6

The agreement is not good but the general tendency is the same, as there is a marked excess in the lower part of the stem and an even greater deficiency in the upper half. The data, admittedly, are scanty, but additional information would be unlikely to alter the general tendency.

It is interesting to compare our figures for this species with those given by Gevorkiantz and Hosley (1) for the same species in the United States. The American material was from 15 to 60 years of age.

Form-class.		*10*	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
65	Great Britain .	96·0	89·8	83·4	73·4	64·1	52·1	40·1	24·8	11·2
	United States .	94·8	89·0	82·5	74·7	65·0	53·7	40·0	24·6	11·1
70	Great Britain .	97·0	90·9	85·5	77·8	70·5	59·1	45·2	30·7	15·4
	United States .	95·7	90·7	84·9	78·4	70·0	59·2	44·7	28·0	13·0

There is quite a strong resemblance between the two series of figures and the agreement in the upper part of the stem is particularly good; the values for the 10 per cent. section, however, are much larger in our material.

Douglas Fir (*Pseudotsuga taxifolia* Brit.). Douglas fir is represented by measurements of almost 500 trees, of which 472 were used in the actual investigation. Most of these were obtained in sample plots distributed all over the country from Ross-shire in the north to Somerset and Wiltshire in the south, but about 100 trees were measured in the old plantation of Douglas fir at Taymount, Perthshire. The bulk of the information refers to trees of less than 30 years of age, but the trees from Taymount were between 60 and 70 years old, and, though by no means mature, were very much larger than most of the others which were measured.

Root swelling affected the measurement in about 90 per cent. of the stems, and was absent only from some of the smallest trees. After the elimination of this factor the series shown in Table XXI were obtained.

TABLE XXI. *Douglas Fir.*

Form-class.	*No. of trees.*	*Girth as a percentage of breast-height girth at per cent. of the stem above breast height.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
55	7	93·0	82·8	75·4	65·5	55·1	48·5	41·5	27·4	13·1
60	74	94·2	85·5	78·2	70·0	60·2	50·7	39·8	27·7	15·0
65	182	94·8	87·0	81·6	73·9	65·4	54·5	43·8	31·1	16·0
70	153	96·0	91·1	84·0	76·9	69·2	60·5	49·3	33·6	17·0
75	46	97·1	93·0	88·2	82·3	74·6	65·1	53·4	37·3	17·7
80	8	97·4	94·4	91·4	86·0	79·5	70·6	59·0	40·9	18·1
85	2	97·9	95·1	92·5	88·7	84·5	77·5	71·6	56·6	25·0

On comparing the averages for form-classes 65, 70, and 75 with the theoretical values given by Jonson's and Behre's curves, we obtain the differences which are shown in Table XXII.

TABLE XXII. *Douglas Fir.*

Form-class.	*Theoretical Curve.*	*Difference between actual and theoretical values at percentage heights.* 10	20	30	40	50	60	70	80	90
60	Höjer-Jonson .	+1·2	..	+0·6	+0·9	+0·2	+0·6	+0·4	..	+0·4
	„ (S. pine) .	+1·1	−0·2	+0·4	+0·7	+0·2	+0·8	+1·1	+1·7	+3·0
	Behre . .	+1·1	−0·2	+0·4	+0·8	+0·2	+0·7	+0·7	+0·4	+0·7
65	Höjer-Jonson .	+0·6	−0·8	+0·7	+0·5	+0·4	−1·1	−1·2	−1·6	−2·0
	„ (S. pine) .	+0·5	−1·0	+0·5	+0·4	+0·4	−0·9	−0·5	..	+1·0
	Behre . .	+0·4	−1·1	+0·4	+0·3	+0·4	−0·8	−0·5	−0·6	−1·1
70	Höjer-Jonson .	+0·8	+1·2	..	−0·6	−0·8	−0·9	−2·0	−5·2	−5·7
	„ (S. pine) .	+0·7	+1·1	−0·1	−0·6	−0·8	−0·6	−1·3	−3·6	−2·4
	Behre . .	+0·5	+0·8	−0·9	−0·9	−0·8	−0·3	−0·7	−3·2	−3·6
75	Höjer-Jonson .	+1·0	+1·3	+1·3	+0·9	−0·4	−2·4	−4·8	−9·3	−11·6
	„ (S. pine) .	+0·9	+1·1	+1·2	+0·8	−0·4	−2·2	−4·2	−7·5	−7·9
	Behre . .	+0·7	+0·7	+0·7	+0·5	−0·4	−1·5	−2·8	−5·5	−7·3

The differences are of the usual type. In the lowest form-class (60) there is an excess all along the stem except at the second point of measurement where the actual values are less than those obtained from the formulae. As the form-classes rise in value, the deficiency in the upper part of the stem becomes more pronounced and is greatest in form-class 75, the highest class which is represented.

In individual stems of Douglas fir there was a good deal of irregularity. This was due in most cases to the coarse growth of many of the plantations and to the nodal swellings caused by the prolonged retention of the branches. These irregularities extended also to the oldest and largest of the trees which were measured.

An attempt was made to separate the data from the older stems from those which were young and still definitely immature. Unfortunately, owing to the scanty nature of the data, it has proved impossible to obtain for any one class a good series of values derived from old trees.

Western Red Cedar (*Thuja plicata* D. Don.). Only a restricted number of trees was available in this interesting species, and the figures which are presented here are based on the measurement of 41 stems of which none was more than 30 years of age at the time of measurement.

Root swelling was present in the great majority of the trees even at this early age, and it was in many cases of quite a pronounced character. After it had been eliminated, the series shown in Table XXIII were obtained.

TABLE XXIII. *Thuja plicata.*

Form-class.	*No. of trees.*	*Girth as a percentage of breast-height girth at per cent. of the stem above breast height.* 10	20	30	40	50	60	70	80	90
55	4	94·1	85·9	75·4	64·8	55·4	44·5	33·3	19·8	5·3
60	11	95·2	88·6	79·2	69·4	60·8	49·2	37·1	21·2	9·8
65	18	95·0	88·2	82·1	74·1	65·1	53·9	42·1	26·0	11·6
70	6	95·8	91·3	84·6	78·8	69·9	59·8	47·3	31·2	13·3
75	2	95·4	91·3	85·4	80·4	73·7	64·8	53·1	43·2	22·6

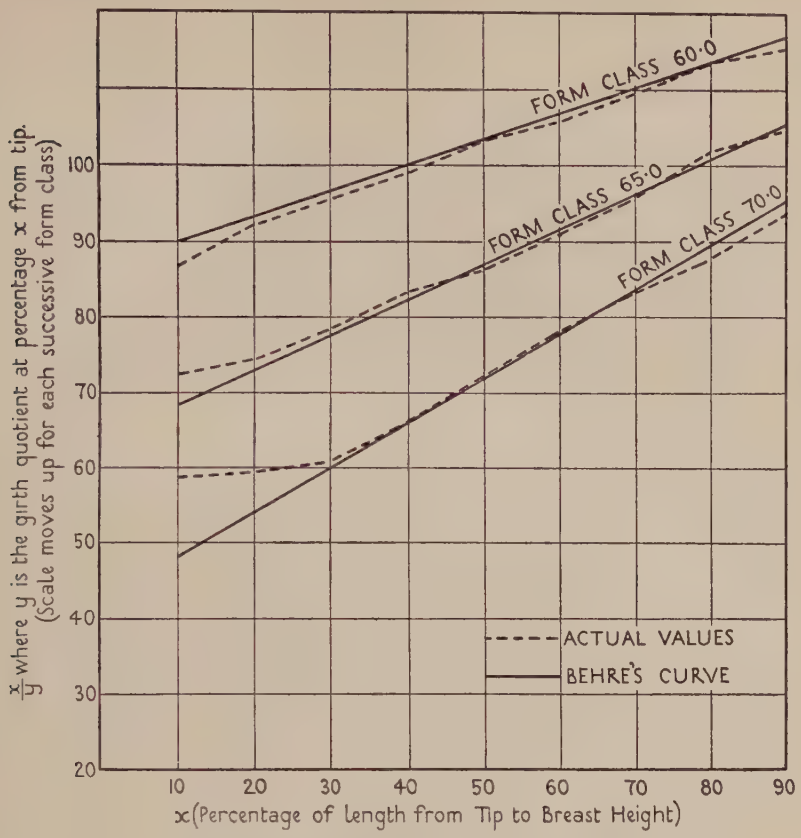

Fig. 5. To show the conformity of Douglas Fir to Behre's Curves.

The various figures given in this table are averages of very small numbers of measurements and cannot be regarded as satisfactory. Nevertheless, it is of interest to compare the values for the form-class (65) which is most fully represented with the theoretical values from Behre's and Jonson's equations.

Table XXIV. *Thuja plicata.*

Form-class.	*Theoretical Curve.*	*Difference between actual and theoretical values at percentage heights.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
65	Höjer-Jonson (Scots pine)	+0·7	+0·2	+1·0	+0·6	+0·1	−1·5	−2·2	−5·1	−3·4
	Behre . .	+0·6	+0·1	+0·9	+0·5	+0·1	−1·4	−2·2	−5·7	−5·5

The agreement in the lower part of the stem is fairly satisfactory although there is a definite excess; in the upper part of the stem there is the usual deficiency. There appears to be little to choose between the curves in point of suitability.

Western Hemlock Spruce (*Tsuga heterophylla* Sarg.). Twenty-three young trees of this species were measured, and after the elimination of root swelling the following series were obtained (Table XXV):

TABLE XXV. *Tsuga heterophylla.*

Form-class.	*No. of trees.*	*Girth as a percentage of breast-height girth at per cent. of the stem above breast height.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
55	1	93·8	86·2	76·2	70·0	56·2	45·0	31·2	16·2	8·8
60	7	95·8	89·6	81·2	71·9	60·4	46·7	31·7	17·2	8·3
65	4	96·4	92·4	83·6	76·1	65·8	50·8	36·2	19·9	8·6
70	9	96·7	92·1	87·2	78·3	69·8	59·5	44·5	26·1	13·3
75	4	97·7	96·4	91·1	84·4	74·7	61·8	45·5	29·3	16·5

The data for the classes most fully represented, 60 and 70, show that the form of the stem in the young hemlock spruce in Great Britain is similar in trend to that of other young conifers. A comparison with Behre's values for these form-classes shows that the differences though similar in kind are exaggerated, that there is a great excess in the lower part of the stem and a serious deficiency in the upper part. This tendency, at least in the upper part of the stem, had already been observed in the Eastern Hemlock Spruce (*Tsuga canadensis*) and a new set of values has been drawn up for this species (2).

Comparisons with Behre's curve and with the special values for the Eastern Hemlock are given below (Table XXVI).

TABLE XXVI

Form-class.	*Theoretical Curve.*	*Difference between actual and theoretical values at percentage heights.*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
60	Behre . .	+2·7	+3·9	+3·4	+2·7	+0·4	−3·3	−7·4	−10·1	−6·0
	„ (Hemlock)	+1·5	+2·2	+1·2	+1·2	+0·4	−1·8	−3·7	−4·3	+0·1
70	Behre . .	+1·2	+1·8	+2·7	+0·5	−0·2	−1·2	−5·5	−10·7	−7·3
	„ (Hemlock)	+0·5	+0·6	+0·8	−0·7	−0·2	+1·1	..	+0·9	+3·0

The special values for hemlock spruce in the eastern United States thus appear to correspond much more closely to the averages from the material in Great Britain than the values given by the general equation.

Abies grandis Lindl. Forty trees of this species were examined at Novar, Ross-shire, in a plantation which is now 33 years of age. Measurements have been taken on three separate occasions in 1926, 1929, and 1932.

Root swelling was present on about 60 per cent. of the trees and was eliminated in the usual way.

The values obtained for the various form-classes are shown in Table XXVII.

TABLE XXVII. *Abies grandis.*

Form-class.	*No. of trees.*	*Girth as a percentage of breast-height girth at*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
		per cent. of the stem above breast height.								
55	1	94·1	84·8	75·3	65·9	56·4	43·9	33·4	23·0	10·5
60	3	95·0	88·0	79·4	71·3	59·9	51·3	35·4	23·1	10·9
65	11	94·7	88·5	81·0	73·2	64·7	55·0	43·3	30·3	15·5
70	18	95·7	90·0	84·5	77·5	69·2	59·9	47·3	33·3	16·1
75	7	96·8	92·2	86·2	79·4	73·6	64·2	52·0	35·9	18·2

Comparing the values for form-class 70 with Behre's theoretical values for the same form-class we obtain the following differences.

	10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
Difference	+0·2	−0·3	..	−0·3	−0·8	−1·0	−2·7	−3·5	−4·5

The lower part of the stem is thus seen to correspond very closely with the theoretical values, but as usual, there are deficiencies in the upper sections.

Abies nobilis Lindl. Thirteen young trees of this species were measured in a plantation at Durris, Kincardineshire, in 1926 and 1931.

The following values were obtained after the elimination of root swelling (Table XXVIII).

TABLE XXVIII. *Abies nobilis.*

Form-class.	*No. of trees.*	*Girth as a percentage of breast-height girth at*								
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
		per cent. of the stem above breast height.								
65	6	95·7	90·4	83·7	74·7	65·3	54·3	40·8	26·8	11·6
70	2	95·8	90·8	86·1	76·4	69·2	58·2	44·4	27·7	14·8
75	5	96·3	93·2	87·7	81·4	74·0	63·1	51·3	35·9	20·7

In Table XXIX we have given for form-class 70, the class which is probably the best represented of all the classes, the form quotients at different heights on

TABLE XXIX. *Form-class* 70.

Species.	*Girth as a percentage of breast-height girth at*								
	10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
	per cent. of the stem above breast height.								
Norway spruce .	95·8	90·6	84·7	77·9	70·0	60·5	49·6	36·0	19·0
Sitka spruce . .	95·8	90·5	84·7	77·9	70·3	61·1	48·7	33·8	16·4
European larch .	95·7	90·1	84·6	77·6	69·9	59·6	48·9	34·4	16·3
Japanese larch . .	96·2	90·8	84·4	77·5	69·5	60·8	48·9	33·7	14·9
Scots pine . .	95·9	90·4	84·8	78·3	70·7	61·7	50·7	35·3	18·5
Corsican pine . .	96·0	90·8	84·8	78·2	69·9	60·3	49·8	36·8	20·8
Douglas fir . .	96·0	91·1	84·0	76·9	69·2	60·5	49·3	33·6	17·0

the stem for the seven most important species. These form quotients are the crude averages obtained from actual field measurements after the effect of root swelling had been eliminated, and they represent, therefore, what has actually been found.

This table emphasizes the close resemblance among these species in respect of the form of the stem under bark after the influence of the root swelling has been eliminated from the data. For the greater part of its length, each species has very much the same form as its neighbours, and it is only towards the very tip that marked differences begin to appear. Irregularities do exist, but it must be remembered that the figures have been derived mainly from measurements of young, and therefore irregular, stems.

It has thus been shown that the under-bark form of the stem is substantially the same in all the important coniferous species in Great Britain, and there are indications that the form of some of the less important trees conforms also to the general type.

It now remains to discuss what use can be made of these facts which have been established.

(To be continued.)

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THE BROWN FOREST SOILS OF ENGLAND

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MORPHOLOGY.

THE Brown Forest soils take their place in the world classification of soils as a type of stable but immature soils which are specifically a product of the climatic and ecological conditions reacting upon suitable parent material in the temperate zone. The maritime climate of England with its rapidly alternating periods of rain and sunshine, its moderate extremes of temperature, and its wet and dry seasons not too distinctly separated, make these Brown Forest soils one of the dominant types of the country. They are formed primarily under and in conjunction with broadleaved forest on heavy soils with a definite water table. The type persists for some years after the cutting and clearing of broadleaved forest, although a slightly different series of reactions takes place and the profile becomes somewhat modified. This will be discussed later. The general effect of a broadleaved tree upon the soil in which it grows is to return to the soil, by the decomposition of its annual leaf-fall, those minerals abstracted for leaf formation during the growing period. The concurrent effect upon the water table is very important, since under broadleaved forest two separate and distinct water zones exist in the soil at the same time. The ground-water level in consequence of leaf transpiration tends to be lowered, while the close canopy and dead leaf-litter tend to prevent surface evaporation. Owing to the high moisture-holding capacity of the humic horizon, percolation is slowed down though not entirely suspended. We thus have the phenomenon of a wet zone in the *A* horizon, over a drier zone in the *B* horizon, superimposed on the permanently wet zone of the ground water. As it is supposed that the tree draws its mineral supply from some depth, it might be expected to enrich the surface with the equivalent of the mineral material from the dead leaf-litter, but that this does not occur in fact is due to the solvent action of percolating water. The leaching power of this water is reduced in proportion to the amount of mineral matter held in solution from the decomposing litter, so that, although water does pass down the profile, both its quantity and its leaching power are controlled by canopy and litter. The effect on the visible profile may be described as 'leaching without bleaching', and this is a peculiar property of the Brown Forest soils. Such leaching expresses the moving down from the surface horizon of calcium carbonate and the finer mineral particles into the illuvial horizon immediately beneath. The apparent absence of iron colourings in the A horizon is attributed to masking by dark humic matter, but the view that the mobility of the iron is purely mechanical is open to question.

Morphologically, the type is characterized by three definite horizons, *A*, *B*, and *C*, while in some cases a fourth, the *G* or gley horizon, may occur.

The A horizon. This is the layer principally subjected to the influences at work on the soil surface; it contains humus in the form of fully and partly decomposed vegetable organic matter intimately mingled with the mineral material to give a distinct dark brown colour.

The structure is 'granular' [1] with a tendency for the structural elements to increase in size to 'small nutty' towards the bottom of the horizon, changing to 'small prismatic' in the *B* horizon.

The consistence is generally 'loose porous' (1–3 mm.), but in soils containing much surface vegetation, as in open canopy, 'cavities' of worms and other fauna frequently open up the horizon to a marked degree.

The occurrence of free calcium carbonate is rare, since weathering is generally complete, and the horizon is in a state of stable equilibrium. (If free calcium carbonate were present in the *A* horizon the soil would be a Rendzina.) Compared to the *B* horizon, it is poorer both in soluble material and clay, although it always contains exchangeable calcium.

The B horizon. This is considered to be an accumulation horizon of the materials washed in from above. Little or no humus material occurs unless it has been mechanically incorporated by biotic action. Because the horizon is higher in clay content, it is usually richer in absorbed bases.

The *structure* is usually 'small prismatic' with a tendency for the structural elements to increase in size with increasing depth. The *consistence* is compact, due to inwash of fine material from above, and this may be felt by scraping the face of the profile with the fingers. The presence of calcium carbonate may sometimes be detected towards the bottom of this horizon. The characteristic colour of the *B* horizon is responsible for the type name, the visible features being the uniform distribution of brown, well-oxidized, iron compounds so intimately mingled with the structural elements as to give the impression of a self-coloured horizon.

The Gley horizon. In soils derived from heavy clays or under the influence of a high water-table, a gley horizon may occur within the zone of fluctuation of ground water. It is characterized by the blue-green varnish, due to compounds of iron in various degrees of oxidation and hydration, on the faces and edges of the structural elements. Concretions, specks, and flakes of iron oxides occur inside the structural elements, while grains and dendrites of manganese dioxide are often widely distributed throughout the upper portion of the horizon.

In the case of the Kimmeridge Clay a zone of accumulation of calcium sulphate in the form of fine crystals occurs at the base of the *B* horizon below the gley and usually at about 1½ metres depth.

The structure of the gley horizon is interesting in that there is a sharp change from the prismatic structure of the higher horizons. The prisms change to

[1] The terms used in describing structure and consistence are those recommended and used by Zakharof in the *Morphology of Soils*, U.S.S.R., 1927.

pyramids or triangular prisms lying longitudinally with one corner or edge always set upwards to give the appearance, in section, of an inverted V. The size of the elements varies between 2 and 20 centimetres.

The consistence of the gley is difficult to determine owing to its moisture content, the elements are compact in themselves, but the horizon as a whole is liable to slip on exposure, due to water percolating between the faces of the structural elements.

The structure of the calcium sulphate zone is finely prismatic, the size of the elements being about 2 to 3 mm.

The C horizon. Below the *B* horizon is found the weathered parent material. The structure and consistence of this horizon is usually variable and indefinite due to the proximity of the unweathered geological material.

CHEMISTRY.

The chemical reactions involved in the formation of Brown Forest soils may be explained if it is taken as a premise that at least two separate soil solutions are present in the soil at the same time. One of these solutions is the percolating stream of gravitational water which in these soils is either neutral or slightly acid, but never alkaline. This stream travels downward through the interstices between the structural elements. The other solution originates at the water table; it contains the products of the hydrolysis of the parent rock, and may be neutral or alkaline, but never acid. It moves upward partly by capillarity, but chiefly in some intimate manner over the absolute soil crumbs and through the structural elements. For want of a better term this may be called the 'soil transpiration current'. Its effect may be observed in the so-called 'white lands' of England, where field drains may be running, at the same time as a white efflorescence of calcium carbonate appears on the soil surface.

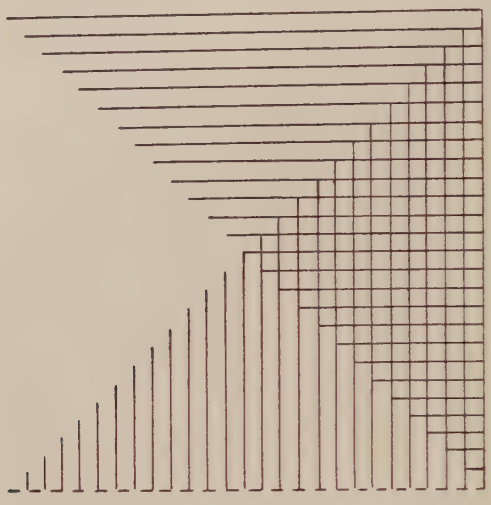
The percolating water contains oxygen and carbon dioxide and those products of the decomposition of organic matter which in the case of the podsols occur as dispersed colloids, rendering mobile such elements as iron, aluminium, and manganese. These colloidal *sols*, according to Morison and Sothers, may carry iron in the ferrous condition.

These soil-water movements are represented diagrammatically in Fig. 1.

Assuming that the lability of sesquioxides in podsolization is due to downward moving humus *sols*, precipitation would occur when the descending and hydrion-charged humus complex meets the hydroxylion-charged soil transpiration current. The assumption is supported by observation in the field of the manner in which humus and sesquioxide accumulations are disposed in relation to each other and to the parent material. For example, in podsols the humus *sol* is readily precipitated by hydroxylions, so that the humus is always superimposed upon the iron zone which requires a greater concentration of hydroxyl ion for precipitation. Lastly, there occurs the precipitation of the residual iron and the bulk of the manganese in a lighter coloured zone just above the *C* horizon and in the zone of domination of the ground water.

In the Brown Forest soils, however, the almost neutral humus is not disper-

sible and in consequence cannot render mobile and transport iron in the form of a ferrous-humus complex. The humus acids decompose certain of the soil minerals and dissolve iron as organic salts, which under the conditions prevailing are rapidly oxidized to form uniformly distributed brown iron oxides throughout the horizon. The precipitation or deposition of manganese compounds does not occur in humus acid solution, so that manganese salts will



Zone in which capillary stream is dominant. ═
„ „ percolating „ „ ‖
„ of intensity of interaction and initial horizon formation. ##

remain in solution until the influence of the alkaline ground water-column becomes dominant. Manganese carbonates are then precipitated (and subsequently oxidized) in quantities increasing with depth until the zone of reduction is reached. Here, though manganese salts may be present, the typical dendrites and grains of the dioxide cease to appear.

These precipitations and oxidation reactions are, in the main, irreversible under the conditions in which they occur, but apart from them an upward and reversible movement of soluble material is also in operation at various seasons. The result is that the whole soil profile remains fairly stable and only grows deeper with age. It is evident that in such a series of reactions no very great changes in the mineral constituents can occur, so that the soil exhibits many of the chemical characteristics of the parent material. In consequence the Brown Forest soils give rise to a larger number of varieties (Bodenarten) than any other world type.

BIOTIC INFLUENCE.

An important factor in soil-forming processes is the interference by man in his utilization of the soil. Since man and his implements have encroached upon the natural forests, certain changes in the soil may be traced directly to his

influence. The soil component most susceptible to the influence of man is the water and directly or indirectly all its subsequent reactions.

It may be assumed that in England and under broad-leaved forests, heavy canopy generally depresses surface evaporation, while the trees transpire water removed mainly from the ground water zone. It depends, therefore, upon climate, height of water table, and density and variety of canopy whether the dominant stream of soil solution is upward or downward.

The first result of cutting and clearing broadleaved forest is to upset the relation between the ground water and the upper wet zone by the increased evaporation and drying out of the latter. The ground water rises, and the capillarity stream becomes increasingly active, while at the same time the organic matter (leaf-litter) decomposes, and the percolating stream increases in intensity. In a short time complete contact is made throughout the profile so that the percolating and capillary stream reactions become speeded up, while slight variations in local climate have an immediate influence upon the soil surface. The result of these reactions is an immediate destruction of the good surface structure.

The cessation of leaf-fall with its consequent return of mineral material to the surface now allows of an increase in the dissolving power of the percolating stream, and the loss of organic matter also depresses the activities of earthworms and consistence is adversely affected. Soils thus 'degraded' do not exhibit clearly defined horizons, but tend to change gradually all down the profile.

In soils which have been long under the plough the *A* horizon exhibits few of the characteristics to be seen in a natural forest soil. Absence of leaf-litter brings about a loss of humus, so that the *A* horizon is no longer characterized by the dark-brown colour masking iron colorations, but tends to be light brown with numerous separate mineral particles which may or may not have grain structure. Because leaves are no longer returning minerals to the soil, the percolating water contains less soluble material and the general equilibrium is disturbed. It must be remembered, however, that in the absence of litter, acid humus compounds cease to exist. The tendency is thus towards leaching and incipient podsolization which, however, does not occur owing to increased surface evaporation caused by removal of canopy and the consequent rise of salts. Equilibrium is once more established. The result therefore of cutting and clearing natural forests is to change a stable Brown Forest soil to a *degraded* but equally stable Degraded Brown soil.

JOHN NISBET

BY H. M. STEVEN

IN this article an attempt will be made to estimate Nisbet's influence on forestry in Great Britain. That influence was exerted partly by his teaching at the West of Scotland College of Agriculture, Glasgow, and advisory work in Scotland, and in particular the west of Scotland, and partly, and to a much wider circle, by his books. I did not know Nisbet personally, hence must rely on his books, but Dr. John Sutherland has kindly placed biographical data and his personal knowledge of Nisbet at my disposal.

John Nisbet was born in Edinburgh in 1853, and was educated at Edinburgh Institution, and at the Universities of Edinburgh and Munich, being a Doctor of National Economy of the latter university. He entered the Indian Forest Service in 1875, became Conservator of Forests, Burma, in 1895, and retired in 1900. He was decorated with the Kaisar-i-Hind Gold Medal at the Delhi Dunbar, 1903. He was Lecturer in Forestry at the West of Scotland Agricultural College from 1908 to 1912, and was Advisor in Forestry to the Scottish Board of Agriculture from 1912 until his death on 1 December, 1914. His publications include: *British Forest Trees*, 1893; *Protection of Woodlands*, 1893; *Essays on Silvicultural Subjects*, 1893; *Studies in Forestry*, 1894; *Burma under British Rule*, 1901; Articles on forestry in the *Victoria History of the Counties of England*, 1903–7; *The Forester*, 1905; *Our Forests and Woodlands*, 2nd edition, 1908; and the *Elements of British Forestry*, 1911.

It is interesting to compare Nisbet with Schlich. Both were trained in Germany, and both had distinguished careers in the Indian Forest Service, but their contributions to forestry in this country have been quite different. When Schlich began teaching at Cooper's Hill, his task was to train men for the Indian Forest Service. There were no suitable text-books in English, and he proceeded to write his *Manual of Forestry*. The sources from which he drew his material were almost entirely German, and the particular quality of his mind enabled him to distil the essence of central European experience, and present with great success principles and generalizations in a subject which is, in a marked degree, local. This no doubt explains the wide use which has been made of Schlich's *Manual of Forestry* in all English-speaking countries, and its influence particularly through university-trained men. This manual, however, has no roots in such national tradition and practice as existed in this country.

Nisbet, on the other hand, was interested primarily in forestry in this country, and in its development. In the Preface to *The Forester* (1905) he stated: 'These new volumes are intended to serve as a text-book, dealing chiefly with British Forestry and Arboriculture (two really separate branches of Rural Economy, which have usually been synonymous in Britain) and with the reasonable possibilities there are of improving the existing condition of our woodlands, and of planting waste land for the growth of timber on business

principles, with a fair prospect of profit. . . . The book thus differs entirely, both in its specific aim and in the handling of the matter it contains, from the only other complete manual of modern forestry as yet published in this country.'

Nisbet edited the sixth edition of Brown's *Forester* in 1894. He found much in the original text with which he did not agree, and that was at variance with the then continental views, but he generally left these statements, and added his own views. When this book came to be revised again he decided that so little of Brown should remain that it should be considered a new work. Thus while Nisbet's views were those of central Europe, they were to some extent grafted on to the earlier British tradition, which of course was not of entirely native development. Moreover, he strove to interpret continental views in terms of British conditions.

The principal merit of Nisbet's books, particularly the *Forester*, which he stated was the essence of all the other books he had written up to that time, is the exhaustive nature of the information they contain. They are mines of information and detail. Such books, however, suffer from the defect of their merit, namely, principles are apt to be obscured. To the earnest seeker after facts, however, these books are veritable treasure troves.

The types of reader Nisbet had in mind were the landowner, the land agent, and the forester. To many a practical forester the *Forester* has been his forest Bible, enabling him to get to know not only the theory, but also the practice of forestry, in this country beyond his own experience, and in central Europe, the home of systematic forestry. Forestry in this country has owed much to the many intelligent and able practical foresters, and many of them in turn owe a great deal to Nisbet's teaching.

Nisbet sought to advance his aim of bringing the riches of central European experience to British forestry not only through his books and teaching, but also by interesting landowners in continental forestry. In 1911 he conducted a party of seven or eight landowners on a tour of German forests.

Nisbet undoubtedly rendered a great service to forestry in this country, particularly in Scotland. He made continental forestry experience available to those interested in forestry, and in a way which was intelligible to the practical forester with a moderate amount of education as well as to those who had greater educational opportunities. That was a necessary step in the development of forestry in this country. Successful forestry in any country cannot be secured by importing ready-made practices; it must develop out of the inherent conditions of that country, but it is of inestimable value to know what other people's experience has been, and to import ideas which can be allowed to germinate and develop under the particular conditions, biological and economic, that are present. That Nisbet helped to do.

REPORT ON THE USES FOR VARIOUS EMPIRE WOODS BOTH HOME-GROWN AND OVERSEAS, AS DISPLAYED AT THE FORUM CLUB EXHIBITION, LONDON

February 1933

BY MAJOR JOHN R. COSGROVE, D.S.O., M.C.

A LARGE variety of woods were shown to considerable advantage at the Exhibition recently staged by the Forum Club, London, and arranged by the Empire Marketing Board, in the form of well-designed furniture and household ornaments, and timber in the natural piece. For the sake of clearness the uses are listed against each wood, together with the name of the maker where available.

HOME-GROWN

Yew (*Taxus baccata*)

Carved Wall Mirror Frame, circular in form, and toned in colour to give a deep rich shade.

Small Coffee Table,

As Exterior of Cigarette Box (lining in Honduras cedar—*Cedrela mexicana*). All by Gordon Russell Workshops, Broadway, Worcestershire.

Cherry (*Prunus Avium*)

As Table Bookcase, dovetail joints.

Mirror, finished almost in natural colour, using the grain to considerable effect.

In Cocktail Cabinet in association with walnut and other woods. (Gordon Russell Workshops, Broadway, Worcestershire.)

Sycamore (*Acer Pseudoplatanus*)

Desk Chair upholstered in leather to suit light colour of the wood. (Gordon Russell Workshops.)

In Wood-Cut Picture. (Brook Art Galleries, Brook Street.)

In parts of Tennis and Badminton Racquets in the Sports Goods Exhibit.

Walnut (*Juglans regia*)

Chair. (Gordon Russell Workshops.)

Cabinet, in combination with other woods such as laburnum and rosewood. (Gordon Russell Workshops.)

Nest of Circular Tables, in combination with Bombay rosewood. (Bath Cabinet Makers Co., Ltd., Lower Bristol Road, Bath.)

Sideboard, in combination elm burr and mahogany interior. (Bath Cabinet Makers Co.)

Dining Table, with elm burr. (Bath Cabinet Makers Co.)

Bookcase Cabinet. (Bath Cabinet Makers Co.)

Cabinet, with many inlaid woods. (Bath Cabinet Makers Co.)

Cabinet, with inlays of ebony. (Bath Cabinet Makers Co.)

Desk, showing the excellence of modern craftsmanship. (Edward Barnsley, Froxfield, Petersfield, Hants.)

Nest of Three Inlaid Tables. (Edward Barnsley, Froxfield, Petersfield, Hants.)

Folding Table. (Edward Barnsley, Froxfield, Petersfield, Hants.)

Lamp Standard. (Edward Barnsley, Froxfield, Petersfield, Hants.)

Sideboard, in combination with Indian laurel, wherein these woods matched each other so well that it was difficult to tell them apart. (J. D. Stark, c/o Messrs. John Lewis & Co., Oxford Street, W.1.)

Plywood Panel. (Venesta Ltd., Vintry House, Queen St. Place, London, E.C.4.)

Elm, Elm Burr (*Ulmus* sp.)

As figured veneer in effective combination with walnut, rosewood, and inlays of various other woods, used in Sideboard, Dining Table, and Cabinet. (Bath Cabinet Makers Co.)

Oak, Brown oak, Bog oak, Pollard oak (*Quercus* spp.)

Brown Oak Cupboard on chest of drawers. (Gordon Russell Workshops.)

Bog Oak for decorative lines in Clock Case with Rosewood. (Gordon Russell Workshops.)

Pollard Oak (resembling elm burr), in Sideboard with figured ebony decoration. (Bath Cabinet Makers Co.)

In Flooring Panel. (Acme Flooring & Paving Co. (1904) Ltd., River Road, Barking, Essex.)

Pear (*Pyrus communis*)

For inlay in Shoe Cabinet and Millinery Chest, and again in Cabinet for the same purpose, by the Bath Cabinet Makers Co.

Laburnum (*Laburnum anagyroides*)

As handles on Chest of Drawers in Brown oak and as decorative 'oyster' veneers in Cocktail Cabinet. Both by Gordon Russell Workshops.

Ash (*Fraxinus excelsior*)

For Hockey Sticks, Cricket Stumps, Tennis and Badminton Racquet frames in the Sports Goods Exhibit.

London Plane (*Platanus acerifolia*)

For decorative parts in Tennis and Badminton Racquets in the Sports Goods Exhibit.

Willow (*Salix* sp.)

For Cricket Bats in the Sports Goods Exhibit.

INDIA, BURMA, AND CEYLON

Teak (*Tectona grandis*)

Writing Table, made by Heal & Son Ltd., London, in effective combination with a vellum top.

Low Tea Table, in combination with birch, also by Heal & Son.
Brush Backs, in the form of men's hair-brushes, where the timber looked attractive in comparison with the white bristles.
In Flooring Panel. (Acme Flooring and Paving Co.)

Indian Laurel (*Terminalia tomentosa*)
In Sideboard in combination with home-grown walnut, wherein these woods are so well matched it was difficult to distinguish them. (J. D. Stark, c/o Messrs. John Lewis & Co.)
Cabinet with mother-of-pearl inlay. By Heal & Son.

Indian Silver Grey Wood (*Terminalia bialata*)
Brush Backs, in the form of men's hair-brushes where the timber finished and looked well.
Plywood Panel. (Venesta Ltd.)

Indian Rosewood (*Dalbergia latifolia*)
Long Clock Case with Bog oak and ebony decoration. (Gordon Russell Workshops.)
As Stand for Cocktail Cabinet. (Gordon Russell Workshops.)
Nest of Circular Tables, in combination with home-grown walnut. (Bath Cabinet Makers Co.)
Cabinet as inlay work with home-grown walnut and other woods.
Ornamental Turnery. By A. L. Hetherington.

Ebony (*Diospyros Ebenum*)
Long Clock Case as decorative inlay. (Gordon Russell Workshops.)
Shoe Cabinet and Millinery Chest as inlay. (Bath Cabinet Makers Co.)
Cabinets as inlay with various other woods. (Bath Cabinet Makers Co.)

Gurjun (*Dipterocarpus* spp.)
In Flooring Panel. (Acme Flooring and Paving Co.)

AUSTRALIA

Australian (Queensland) Walnut (*Endiandra Palmerstonii*)
In Bedroom Suite comprising Wardrobe, Dressing Table, Circular Bedstead, and Small Chair. (Betty Joel Ltd., 25 Knightsbridge, S.W.1.)
Wall Mirror. (Heal & Son Ltd.)

Specimen Boards. (Wm. Mallinson & Sons Ltd., 130–40 Hackney Road, London, E.2.)
Specimen Board and Veneers. By Louis Bamberger & Sons.
Door and Board. By Jas. Latham Ltd.
As Plywood Panels. By Venesta Ltd.

Tasmanian Oak (*Eucalyptus obliqua*)
In Dining Table in combination with British Columbia Douglas fir specially treated. By Drytone Ltd.

Jarrah (*Eucalyptus marginata*)
In Flooring Panel. (Acme Flooring and Paving Co.)
Specimen Board. (Wm. Mallinson & Sons Ltd.)

Silky Oak (*Cardwellia sublimis*)
- Specimen Boards and Veneers. By Jas. Latham Ltd.
- Door. By Jas. Latham Ltd.
- Plywood Panel. By Venesta Ltd.

Myrtle (*Nothofagus Cunninghamii*)
- In Flooring Panel. By Acme Flooring and Paving Co.

Australian (Queensland) Maple (*Flindersia Brayleyana*)
- Door and Panel. By Jas. Latham Ltd.
- Plywood Panel. (Venesta Ltd.)

NEW ZEALAND

The Dominion of New Zealand was represented by a series of specimen woods, including Rimu, White pine, Kauri pine, and Tawa.

CANADA

Canadian Birch (*Betula* sp.)
- In Low Tea Table in combination with Teak. By J. F. Johnson of Messrs. Heal & Son Ltd.
- As 'Birnut' Door. (Louis Bamberger & Sons.)
- As 'Birnut' in Flooring Panel. (Louis Bamberger & Sons.)
- In Tennis Racquets. (Dunlop Rubber Co.)

Canadian Maple (*Acer saccharum*)
- Specimen Board. (Wm. Mallinson & Sons.)
- In Flooring Panel; it is one of the best flooring woods known for hard wear. (Acme Flooring and Paving Co.)

British Columbia Douglas Fir or British Columbian Pine (*Pseudotsuga taxifolia*)
- Kitchen Cabinet, dark stained effect. (Drytone Ltd.)
- Dining Table in dark stained effect, with similarly coloured edging of Tasmanian oak. (Drytone Ltd.)
- Three Chairs. (Drytone Ltd.)

BRITISH WEST AFRICA

Nigerian Walnut (*Lovoa Klaineana*)
- For Drawer Linings in Sideboard. (Bath Cabinet Makers Co.)

Nigerian and Gold Coast Mahogany (*Khaya* spp.)
- For Sideboard Interior. (Bath Cabinet Makers Co.)
- In handles of Tennis Racquets, &c., in the Sports Goods Exhibit.

BRITISH HONDURAS

Honduras Mahogany (*Swietenia macrophylla*)
- In Shoe Cabinet and Millinery Chest, decorated with inlaid Ebony and Pear. (Bath Cabinet Makers Co.)

Rosewood (*Dalbergia Stevensonii*)

As decorative inlays in Cabinet with home-grown Walnut. (Bath Cabinet Makers Co.)

BRITISH GUIANA

British Guiana Purpleheart (*Peltogyne pubescens*)

As inlay in Cabinet. (Bath Cabinet Makers Co.)

East African Olive (*Olea Hochstetteri*) and South African Olive (*Olea laurelifolia*)

Both as Ornamental Turnery. By A. L. Hetherington.

The materials and craftsmanship in this Exhibition were excellent and aroused much favourable comment.

SOCIETY'S AND OTHER NEWS

NOMINATION OF OFFICE-BEARERS AND COUNCILLORS

Members are reminded that nominations for election to office at next Annual General Meeting must be in the Secretary's hands by 31 October next. As there is no other opportunity of reminding members, they should act on this notice. There is no special nomination form, the only requirement being that the nominations must be in writing and be signed by two Professional Members (i.e. Fellows or Associates). Nominations are required for the following:

Office-bearers: President, Vice-President, Editor of Journal, Business Editor, Secretary & Treasurer, Auditor.

Councillors: Three members to hold office for years 1934 and 1935.

A list of Councillors now in office will be found at the beginning of the Journal. The three who will retire at the end of 1933 are eligible for re-election.

LORD LOVAT: AN APPRECIATION

By W. L. Taylor

Simon Joseph Fraser, 14th Baron Lovat in the Peerage of Scotland, 3rd Baron in the Peerage of the United Kingdom, and chief of the Clan Fraser died at Chipping Norton on 18 February. To every one who had the privilege of knowing him, and to those who have had the great fortune to have worked under him, the sad tidings must have come with feelings of the deepest sorrow and regret.

Lord Lovat was possessed of a rare personal influence and genius for leadership which none in contact with him could fail to recognize. The key-note of his life was a large-hearted devotion to each of the many causes he took up. He was first and foremost a Scotsman, but his outlook was as broad as the scope of his activities which were Empire-wide; few men in our generation can have given clearer proofs of unselfish and practical patriotism. His raising and leadership of Lovat's Scouts in the South African War of 1900–2 are matters of history; also his distinguished services in the Great War in command of the Highland Mounted Brigade in Gallipoli, France, and Flanders. Subsequently he was made Director of Forestry in France, a post for which none was more suited, and which he filled with conspicuous success so long as the war continued. Among the many honours conferred upon him by British and Foreign Governments, he was made a Knight of the Thistle in 1915, and more recently received the Grand Cross of the Victorian Order. He had long previously received the C.B. and D.S.O. for his services in South Africa.

Lord Lovat succeeded early in life to the extensive family estates in Inverness-shire which he managed and consolidated with such marked business acumen and success. His affection for Beaufort, his beautiful Highland home, was constant throughout his life, and he was, in fact, interested and exceptionally well informed concerning all the manifold problems arising out of the ownership and management of land, as well as in all the natural phenomena of the countryside. He could play as well as work, and while equally at home in the field, on the racecourse, and at games, he was one of the leading game shots of his day. He was Chairman of the Grouse Commission of pre-war days. His interest in forestry can be said to have been lifelong; he was an active advocate of

systematic forestry with all the eagerness and zeal which characterized his every action, and, long before the devastation wrought by the War in the woodlands of Great Britain spurred Parliament to adopt a national forest policy, his advocacy was stamped with the authority of an extensive knowledge and experience of the problems involved. He was included in the membership of the Forestry Sub-Committee of the Reconstruction Committee set up by the Prime Minister in 1916 and known to foresters as the Acland Committee, and was a member of the Interim Forest Authority from its inception in 1918. On the passing of the Forestry Act of 1919 he was appointed the first Chairman of the Forestry Commission, over which he presided from November 1919 until March 1927, when he resigned to take up the appointments of Parliamentary Under-Secretary of the Dominions Office and Chairman of the Overseas Settlement Committee. It was in connexion with the latter appointment that he undertook a particularly onerous tour of the Dominions in support of emigration from this country, an exacting duty which, it is thought, contributed largely to his breakdown in health.

Lord Lovat acted as Chairman of the first Empire Forestry Conference in London in 1920, also of the second of these important meetings which was held in Canada in 1923, and he headed the British delegation to the World Forestry Conference in Rome in 1926.

As Chairman of the Forestry Commission, throughout the strenuous and often trying days of the birth and early infancy of the Department, Lord Lovat was at once leader and inspiration in the rather complicated duties involved in the launching for the first time of a constructive forest policy for the British Isles as enjoined by the Forestry Act of 1919. His remarkable influence and powers as a leader of men in every station in life and every degree of temperament were at once manifest. His wise counsel and diplomacy smoothed the early difficulties inseparable from a work of which the like had never previously been attempted on the same scale by any other nation: the creation of forests where no forests stood and the fostering of a forest sense in which our nation, despite its inherent love of woodland and trees, had become so sadly deficient. He gave himself without stint both in the office and in the field, and his vitality and example, his ready sympathy with all ranks in the new service in their endeavours and difficulties, his humour and kindliness, and, above all, his courtly personality and charming smile gave him a place in the esteem and affection of all who came in contact with him which time will not fade. Britain in these days produces too few such men and truly the world is poorer now that he is gone; forestry and foresters have lost a friend. *Requiescat in pace.*

THE INTERNATIONAL UNION OF RESEARCH ORGANIZATIONS

In *Forestry*, vi, No. 2 an article by Mr. W. H. Guillebaud appeared on the International Union of Research Organizations, Nancy Congress, 1932. The writer regrets the inadvertent omission of the names of the Permanent Committee of the Union, elected at the Nancy Congress, and also of the Commission appointed to deal with Bibliography. The Permanent Committee is composed of the following members:

Professor G. Roth.	Hungary.	*President.*
Mr. E. N. Munns.	United States of America.	*Vice-President.*
Professor P. Guinier.	France.	
Professor H. Badoux.	Switzerland.	
Professor L. Frabricius.	Germany.	
Professor Y. Ilvessalo.	Finland.	
Professor A. Favari.	Italy.	
Sir Roy L. Robinson	Great Britain.	
M. Sven Petrini.	Sweden	*Secretary.*

The members of the Bibliographical Commission are:

Professor R. S. Troup.	Great Britain.	*Chairman.*
Professor H. Weber.	Germany.	
M. H. Perrin.	France.	
Professor W. Jedlinsky.	Poland.	
Dr. P. Flury.	Switzerland.	

The writer of the above-mentioned article desires to take this opportunity of paying a warm tribute to the services of Professor Guinier who, as President of the International Union from 1929 to 1932, also presided over the deliberations of the Nancy Congress. Those members who attended the Congress owe a deep debt of gratitude to Professor Guinier, M. Oudin, and other members of the staff of the Forest School at Nancy for the excellent organization of the Congress which did so much to ensure its success.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION, YORK, 1932

It is regretted that in the list of papers given in *Forestry*, vi, No. 2, page 182, that on 'Preservative Treatment', by Mr. R. C. B. Gardner, was inadvertently omitted. This paper was published in *The Timber Trades Journal*, September 24 1932.

REVIEWS

Der rationalisierte Waldbau. By Karl Philipp. Karlsruhe, Eugen Harsch, 1932. RM. 12.

Review by Professor R. S. Troup

In order to appreciate this book to the full the reader must have known personally the one-time chief of the Baden Forest Service; he must have had the stimulating experience of a day, or preferably several days, with him in the forests, listening with envy to the rich vocabulary and trenchant criticisms of one who never suffered fools gladly and whose opinions bristled with originality; who imposed his ideas on the Baden Forest Department with a forcefulness which disturbed its 'placid contentment' and created some opposition from those who failed to see eye to eye with him. We would expect from Dr. Philipp a highly original book, and we are not disappointed. The wealth of quotations alone raises it above the commonplace: embracing several different languages, these are culled from the writings not only of foresters but also of theologians, philosophers, and others, including Pope Benedict XIV, Nietzsche, Cicero, Goethe, Diderot, Shakespeare, Ruskin, Carlyle, Ford, and several others, and they serve to brighten a text already enlivened by shafts of satire reminiscent of Bernard Shaw.

The book starts by emphasizing the importance of the soil as the groundwork of silviculture; hence, in the process of bringing a forest into an organized state particular care is necessary not to impoverish the soil but to maintain its productivity at the highest level. This is done by careful attention to the forest canopy, keeping in mind the importance of assisting the rapid decomposition of humus while preventing its removal, guarding against wind damage, protecting the soil against the effects of wind and sun, preventing soil-deterioration and weed-growth, and attending to light conditions. There follow short chapters dealing with the forest as a living community and with the silvicultural characters of the principal forest trees, including a few exotic species.

The title, *Rationalized Silviculture*, is at first sight puzzling. The term is defined as involving four main ideas: (1) elimination of waste, (2) simplification of practice and standardization, (3) scientific management, and (4) efficiency: and the forest technician should keep the following principles in view, (1) orderly arrangement (*Ordnung*), (2) protection, (3) production so far as the locality permits, and (4) careful harvesting. The different silvicultural systems are examined from the point of view of these principles. To the author, anything in the nature of irregularity is anathema. For this reason the selection system comes in for severe criticism, and several pages are devoted to pillorying it in two comparative columns, one headed 'Fable', in which its supposed virtues are enumerated, and the other headed 'Truth', in which they are rudely demolished. Uniform regeneration fellings are held to vary in their results with the species concerned: they are, for instance, suitable for beech and Silver fir and for oak in mild climates, but not for spruce, owing to the danger from wind. Shelterwood strip fellings are on the whole satisfactory, but group fellings have serious drawbacks, including the damage done during extraction; these drawbacks are aggravated in the irregular form of crop produced by the Baden *Femelschlag* with its long and indefinite regeneration period. The system to which, above all others, the author pins his faith is the shelterwood wedge system, which provides the ideal conditions in respect of the four principles referred to above.

His belief in this system is based on the experience gained in its practical application in the Reviers of Langenbrand and Huchenfeld, in the Black Forest, where the growing stock consists mainly of Silver fir, spruce, and Scots pine, and the locality is hilly and subject to severe gales from the west and south-west. The system has been subsequently extended to other localities under the author's administration, including the mixed hardwood and pine forests of the Rhine plains, where wind is not so serious a factor. The wedge form of felling may be looked on mainly as a suitable manner of removing the overwood after regeneration has begun, the chief objects being to guard against wind and to prevent damage during extraction. An essential condition for success is the education of the crop by light thinnings at one-year intervals; these furnish an outturn of as much as 60 per cent. of the total from all classes of fellings, and the length of the rotation is thereby reduced by 10 to 20 per cent. The wedge fellings follow as soon as the regeneration of the shadebearing Silver fir has begun to establish itself, and the removal of the old wood then proceeds rapidly as the remaining species regenerate themselves. The author rightly lays stress on maintaining the productivity of the forest by preventing the removal of litter and by preserving a mixture of broad-leaved species in coniferous woods: he also insists on natural regeneration as far as possible. In the form of an appendix are given certain official orders issued by the Forest Branch of the Finance Ministry of Baden during the period when the author was head of it, together with several diagrams and some good photographs illustrating different stages of the wedge system.

The spirit of the book is suitably revealed by a quotation from Ford on p. 153: 'There are always two kinds of people in the world—those who pioneer and those who plod. The plodders always attack the pioneers.' The author is essentially a pioneer, and he must expect the onslaughts of the plodders. Whether the reader will agree with all his views or not, he will at all events find the book both provocative and stimulating, and will find in it much food for thought.

'Sturmgefahr und Anpassung.' By Dr. Kurt Fritzsche. *Tharandter forstliches Jahrbuch*, No. 1, vol. lxxxiv, 1933.

Review by W. H. Guillebaud

THERE can be little doubt that the next generation of British foresters is going to have the importance of the problem of damage by storm forced somewhat rudely upon its attention. There are several reasons for this: in the first place there is the fact that we are now creating extensive even-aged blocks of Sitka and Norway spruces; secondly, the soils on which the bulk of the spruce is being planted are either peaty, or if not peaty the clay fractions predominate in the mineral soils; both of these are conditions militating against deep rooting; thirdly, the meteorological conditions peculiar to these islands (e.g. wet snow blizzards) tend to increase the risk of damage by storm as compared with adjoining parts of the Continent. This being the case, any light that can be thrown on the mechanism of wind throw, and on the counter measures which can be taken, is very welcome. The article under review, of some 90 pages in length, though it does not cover anything like the whole of the problem, contains much that is of interest, and corrects a number of misconceptions which have apparently crept into recent literature on the subject.

In the first section of his article Fritzsche discusses his field observations on a number of recent windfalls in spruce forests in Saxony and adjoining countries. A lengthy chapter then follows dealing with the mechanics of the tree in relation to the forces of

gravity, bending moments due to wind or snow, &c. The physiological adaptation of the tree to wind pressure is then discussed in a very interesting manner, and the article concludes with some observations on the function of the protective margins of stands in sheltering the main block from wind, and also deals with felling series.

The field observations, combined with dissections of roots of wind-firm and uprooted trees, led the writer to the conclusion that by far the most important part in holding up the tree is played by the main lateral roots running parallel to the storm direction but on the leeward side of the tree. That is to say, the tree depends primarily on the strength of its propping roots (*Stützwurzel*). The idea that a tree is anchored to the ground and that when it is swayed over by a gust of wind the chief strain is on the lateral roots to windward which hold the tree as an anchor holds a ship is, according to Fritzsche, entirely erroneous. Again and again observations of actual windblows showed that where isolated trees stood while the rest were thrown they owed their stability not to any exceptional root development on the side from which the storm came, but to one or more strong buttress roots to leeward. Another indication is afforded by the study of root fracture. In the great majority of cases failure occurs through the breaking or shearing of the main lateral roots on the leeward side of the tree; such breakage typically occurs close to the main root in a deep-rooting tree, but from 2 to 5 feet away from the axis in a shallow rooting tree. On the windward side of the tree the roots are out of the ground or held only by their relatively weak extremities.

The behaviour of many of the marginal tree zones affords further confirmation of the major importance of the propping roots. It was found that often where a storm had hit straight on to the face of a stand, the outer marginal trees as well as the interior stand were thrown while the margin zone on the leeward side of the stand remained erect owing to the strong development of propping roots running out into the ride or field behind.

Deductions from field observations alone, however complete the survey, are bound to be open to criticism on various grounds, hence the importance of the somewhat abstract examination of the statics of the tree to which so much of this article is devoted. The conception (due to Metzger) of the stem of a tree as having the properties of a beam of uniform resistance explained much that was formerly obscure about the form and static behaviour of trees, but it is valid only on the assumption that one end of the beam is fixed immovably. The amount and direction of the forces applied at the fixed end as a result of lateral pressure on the stem have been largely overlooked in the past but clearly demand consideration. The writer starts out by comparing the way a tree is held in the soil with the various methods of securing a mast or a tall girder. The closest analogy is to that of a mast the base of which is secured to a broad flat plate, and the plate then bolted down to a concrete foundation. If great strains are anticipated, radiating buttress supports are sometimes attached to the lower part of the mast, the buttress ends resting on the basal plate or embedded in the concrete. In the case of a tree the root axis with the main lateral roots form the equivalent of the basal plate and sustain the weight of the tree with its branches, the downward-going network of smaller roots together with all the included soil (the root ball) constitutes the foundation, and the thickenings on the basal portion of the stem, seen particularly on exposed trees, are analogous to the buttress supports of the mast. As a rule the foundation of a tree is to be regarded as sunk in the soil, the only portions showing above the ground being the stem buttresses (when present) and the upper part of some of the main lateral roots.

When a wind strikes the crown of a tree and bends it over to one side, it sets up stresses at the base, the amount of which depends upon (1) the force of the wind, (2) the centre

of gravity of the stem and crown and its distance from the ground level, (3) the elasticity of the stem, and (4) the weight of the stem, crown, and foundation (roots plus included soil plus certain hypothetical additions as equivalents for the cohesion of the soil at the base of the foundation and for the anchoring action of any small, deep-running roots). An examination of the various types of stresses, compression, tension, and bending set up in the lateral roots shows that the bending strains are incomparably the most important. These bending strains are directed vertically upwards on the windward side of the tree and vertically downwards on the leeward side. Calculation shows that the bending requirements are at least four times as great on the leeward as on the windward side of the tree. When a tree is swayed over to one side by the force of the wind, the centre of gravity of the stem and crown is shifted to that side, and a bending moments is set up in the base at a certain distance from the central axis of the tree. The taller the tree and the greater the wind pressure, the further the distance of the resultant from the axis. When the lateral force is such that the resultant lies outside the basal support the tree must be overturned.

The fact that both the stem and roots of a tree are elastic introduces further factors which have to be taken into account when considering the stresses involved when a tree is swayed over to one side by the wind. One effect of the elasticity of the stem is to bring the resultant nearer to the stem axis than would be the case if the stem were rigid, and so to lessen to some extent the danger of windthrow. But the roots also are elastic and tend to give to the bending pressure, hence the effective radius of the root-plate is not the actual radius but only that portion of it where the roots are sufficiently stiff to resist the bending forces. In deep-rooting trees the roots break as a rule within 12 to 18 inches of the stem, while in the most shallow rooting types the distance rarely exceeds 4 to 5 feet.

Turning now to the question of adaptation, it is well known that any portion of a tree which is under strain tends to thicken at the point of the strain, the mechanism of the stimulus is unknown, but it seems reasonable to assume that at a certain degree of strain a stimulus to growth comes into effect and extra wood is put on. It must also be assumed that there is an interval between the initial or threshold stimulus (*Grenzschwelle*) and the breaking limit. This interval represents as it were a factor of safety. As the strains continue and the root thickens, the force required to reach the threshold stimulus rises and so, probably in increased ratio, does the breaking-point.

In nature, an exposed tree will be subjected to wind from all quarters and will tend to develop supporting roots radiating in all directions. If the wind blows more frequently and strongly from one direction, the tendency will be for the roots on the opposite side from which the wind comes to be the best developed. This is because the stresses are greatest on the leeward side. (It may be remarked that there is an admirable example of such unilateral root development in the spruce plantation occupying the wolves' enclosures at the Whipsnade Zoo. Many of the trees show pronounced buttress development on the north-east side of the trees. Reviewer's note.)

It is in this response to the wind stresses transmitted through the stem coupled with hypothesis of a factor of safety that we find the explanation why deeply crowned isolated or marginal trees are usually more storm-firm than trees with short, high-set crowns. Trees are only able to develop strong roots and retain the lower branches of their crowns where they have sufficient room, but sufficient room normally implies a relatively exposed position, and so a greater amount of pressure per unit area of the crown. The greater the pressure to which the tree becomes accustomed, the smaller the risk of overthrow owing to abnormally high pressures. Thus trees with deep set crowns are not

more storm-firm because their crowns are deep set but because they have grown in the open and so have received the necessary stimuli for strong root development.

The bearing of these considerations becomes clear when we compare the outside trees of a stand with those that have grown up in close canopy in the interior. The outside trees, responding to the wind stresses, develop strong buttressing roots which will be stoutest on the opposite side to that from which the prevailing wind blows, provided sufficient space is available on that side for their development. The inside trees will also be provided with propping roots, but these are typically weakly developed and may be lacking altogether on one side of the tree. A further point tending to promote the stability of the outside trees is that they are usually shorter than the inner trees, and hence the strain on the roots is less. In any case it is important to begin early to expose the trees of an endangered stand to the windstresses and so to enable the roots to respond and stiffen up. Such response is much slower than in the case of the stem. Even a long delayed thinning may produce a marked response on the part of the stem and crown, but it is useless to expect the roots of a stand which is past middle age and has suddenly been opened up to respond quickly to the freer conditions. Fritzsche quotes Zederbauer as saying that in order to produce a spruce root-system which shall be equally storm firm in all directions a minimum space of 1 to 2 square metres per stem is necessary up to about the 20th year, after which more room must be provided by thinning.

In addition to thinning, other measures which tend to increase the physiological depth of the soil are to be encouraged: e.g. drainage of wet soils and the admixture of deep rooting species. The author suggests that the part played by the latter is to provide deep-going root channels which will ultimately be followed by the shallower rooting main species.

In the concluding section of his article Fritzsche proceeds to discuss in somewhat greater detail the part played by the outside trees on the windward side of a stand in protecting the inner trees from being thrown. In the first place he disputes the notion that the outside trees function as a wall which pushes the wind upward as it hits it, only to descend again with added force on the interior of the stand. The outer belt functions rather as a series of lattices which let through the air, but robs it of a large amount of its energy. It is true that there is always an overfall wind, but this is much less violent than if the margin functioned as an impenetrable wall. In those cases where the wind creates a hole in the inside of a stand a downward and more or less rotary draught is set up which tends to eat backward into the stand to windward until the marginal trees are reached. If the storm is not too violent these may remain standing, thanks to the long-continued process of adaptation to wind to which their stem and root systems have been subjected. Should the storm, however, be sufficiently strong the edge trees, lacking the buffering effect of the stand as a whole, are also overthrown.

Some interesting experiments have been made in various parts of Germany in creating an artificial protective margin to a stand by cutting off the tops of a number of the outer rows of trees. The shortenings of the stems and reduction in the area of crown must lessen the risk of windfall, and the method has in fact given excellent results in practice.

Another method of protection against damage by storm is the creation of felling series. These, if sufficiently narrow and steeply graded, provide ideal protection from storms arising from certain directions, but trouble is liable to arise when Dame Nature brings a storm out of the opposite direction to that against which the felling series have been orientated.

To sum up, we have in the inherent capacity of the tree to respond to stresses exceeding a certain threshold value a very important means of safeguarding our forests against

wind. The means, early, frequent, and regular thinnings, creation of felling series, the breaking up of large blocks by severance fellings with the object of creating protective margins, lie to hand. It is up to the forester to make the maximum use of the measures at his disposal.

In conclusion, it may be remarked that virtually no reference is made in the article under review to the adaptation of the stem against windbreak, although it is a well-known fact that stem break is an important feature of most cases of damage by storm. Some treatment of this important aspect of the problem would have been of interest.

Untersuchungen über die Mikrobiologie des Waldbodens. By D. Fehér. Berlin: Verlag von Julius Springer, 1933. Price, RM. 24.

Review by G. V. Jacks.

THIS book is an account of the detailed researches carried out during the last ten years by Professor Fehér and his colleagues in Hungary. In form it is more like a thesis than a text-book, but at the same time it is probably the nearest approach to a text-book devoted entirely to forest soil microbiology that has yet been attempted. The soils investigated were mainly Hungarian, but included some from central Europe and Scandinavia.

The numbers of bacteria in forest soils are usually lower than in cultivated soils, though the variety of species may be greater. The relative paucity of bacteria under forest conditions has been ascribed to the usually high acidity of forest soils, but many factors favourable to microbiological life, and absent from cultivated soils, tend to counteract the inhibitory effect of soil acidity. In particular, the conditions under forest are natural, the micro-organisms adapt themselves to their environment and exist in a state of stable equilibrium with the other species. In cultivated soils, for example, nitrogen-fixing bacteria do not seem to be able to exist below pH 5·6, whereas Fehér found them in forest soils at a pH of 4·8. There is no well-defined relationship between soil acidity and bacterial population, though the numbers of bacteria tend to be lower the higher the acidity. Factors of equal or greater importance are temperature, the air and water capacity of the soil, humus content, &c. The relative importance of these factors varies greatly with the different micro-organisms.

The central object of Fehér's investigations was to relate the annual fluctuations in bacterial population with the seasonal changes in the main climatic, soil, and ecological factors. A large number of lucid diagrams are given which enable the results to be understood even if the reader has only a passing acquaintance with the German language.

The qualitative and quantative changes in the bacterial population of several forest soils were followed throughout the year, and were found to be quite analogous to the seasonal changes in the vegetation. As regards total numbers, a sharp maximum (among aerobic species) occurred towards the end of the summer; the numbers of anaerobic bacteria varied only slightly throughout the year. From studies extending over several years of the many factors affecting bacterial population, Fehér concludes that temperature is the most, and soil water content the next most, important. He suggests the product of temperature multiplied by soil water content as an expression of biological activity at any time.

The ecological behaviour of each group of bacteria—cellulose decomposing, urea and butyric acid forming, nitrogen fixing, nitrifying, and denitrifying—is considered separately and together, but it is perhaps chiefly those organisms connected with the soil nitrogen cycle with which the forester is concerned, and a special chapter is devoted to them.

There was a remarkable similarity in the nitrogen cycle on all the sites examined especially in regard to the periodic changes in total soil nitrogen. A maximum occurred in late spring, followed by a fall throughout the summer, when the nitrogen demands of the vegetation are greatest. Thereafter the soil nitrogen content gradually increased through the autumn and winter, as the newly fallen litter decomposed.

There was, however, no clearly defined relation between nitrogen content and bacterial activity, owing to the fact that the different organisms concerned in the nitrogen cycle interact and have their periods of maximum activity at different seasons. Nitrogen fixing bacteria are active in the latter half of summer, nitrifiers in spring and autumn, when denitrifiers are least active. A connexion could be established between the activity of nitrifiers and the amount of nitrate in the soil, although even this connexion was often disturbed by the influence of other factors, particularly temperature, moisture, the needs of the vegetation and the leaching of nitrates. A somewhat surprising relation was found between the humus and total nitrogen contents—when the former was high, the latter was low, and vice versa, with the result that there were great seasonal variations in the C/N ratios of the soils; in October the ratios were up to ten times as large as in May.

Similar detailed investigations of the ecology of forest protozoa are described by L. Varga in the latter part of the book. As was to be expected from earlier work, an inverse relationship was established between the numbers of protozoa and bacteria at any time, the protozoa reaching their maximum activity in early winter when bacterial activity was at its lowest ebb. From a study of the influence of all the chief environmental factors on the protozoa population, the most striking results that emerged were the close connexion between the water content, and a somewhat weaker connexion between the total nitrogen of the soil, and the numbers of protozoa. Total nitrogen showed a slight maximum in December and January, when the numbers of protozoa were falling rapidly. It is assumed that the soil nitrogen is increased by the death and decomposition of the bodies of protozoa. Very full tables are given of the limits of distribution of 124 different species of protozoa.

A section is also included on the microbiology of alkali soils (by R. Bokor). Although these are not naturally forest soils, they offer a promising field of research to the biologist, as representing some of the extreme conditions under which micro-organisms can exist. It is much to be hoped that the preliminary work described here will be extended. Professor Fehér intends to continue his work and to publish the results in a later book, which will be awaited with great interest.

The Mechanism of Control of Relative Root and Shoot Development. A note by R. N. Aldrich-Blake.

An important reference was overlooked in the writer's discussions (1, 2, 3) on the mechanism of nutritional control of the relative root and shoot development of forest tree seedlings. Eleven years ago Turner (6) advanced a cogent causal explanation of the fact that the vast majority of plants produce a relatively light root under conditions inducing a low carbohydrate/nitrogen ratio and vice versa.

In the first place he brought forward evidence which showed that nitrogenous salts depress relative root weight by virtue of an internal effect on metabolism, rather than through the concomitant increase in concentration of the nutrient solution. He found that barley seedlings grown in water culture with high nitrogen and low total concentration of salts had relatively lighter roots than those grown with low nitrogen and high

total salt concentration. And he quoted two papers in which it was shown that wheat seedlings grown with a plentiful water-supply produced relatively lighter roots than those less generously watered. The amount of readily soluble nitrogenous salts must have been independent of the amount of diluent water, and was thus the same in heavily and lightly watered series. Thus the plants with the relatively heavier roots drew their nutrients from the more concentrated solution. This work, combined with the evidence marshalled by the writer, proves beyond all reasonable doubt that nitrogenous salts depress relative root weight by virtue of an internal effect on metabolism.

Secondly, Turner showed that the growth of isolated roots in culture solution, containing glucose as a source of carbohydrate, was enhanced by increasing the supply of nitrogenous salts. Therefore the reduction of relative root weight in the intact plant is a correlative result, and no direct effect of nitrogen on root growth.

Finally, he concludes with Curtis (4) that an increase of nitrogen supply raises the relative shoot weight by providing relatively more nitrogen in the shoot to combine with the primary products of photosynthesis. Relatively little carbohydrate is left for distribution to the roots.

This involves the assumption that plants starved of nitrogen retain a high relative proportion of the small quantity available in the root, because it is the lack of nitrogen in the shoot which is held responsible for the relatively greater basipetal transfer of carbohydrate in such plants. In *Casuarina equisetifolia* (3) this assumption appears to find support. But reliable evidence will not be forthcoming till we have nitrogen analyses of roots and shoots of many species, each grown with a range of nitrogen supply.

The second assumption implicit in Turner's hypothesis is that the shoot provided with ample nitrogen has the first call on available carbohydrates, and in recent years this assumption has received no small measure of support. Brilliant work by Dutch physiologists has proved conclusively that extension growth of grass coleoptiles is controlled by a substance produced in the apical meristem, and a similar control obtains in the shoot of the dicotyledonous sunflower seedling. Cambial activity in trees is resumed in spring immediately below the swelling buds, whence it spreads downwards in wedges towards the roots. In a recent review on growth regulators Snow (5) has reported his own discovery that the stimulus to renewed cambial activity can cross a protoplasmic discontinuity, even traversing interposed moistened linen sheets. Thus he has adduced good evidence that a hormone descending from the shoot meristem is responsible for the resumption of radial growth.

(1) Aldrich-Blake: *Oxford Forestry Memoir*, No. 12. 1930.
(2) Aldrich-Blake: *Forestry*, vol. vi, No. 1. 1932. pp. 40–52.
(3) Aldrich-Blake: *Oxford Forestry Memoir*, No. 14. 1932.
(4) Curtis: *Cornell Univ. Agr. Exp. Sta. Mem.*, No. 14. 1918.
(5) Snow: *New Phyt.*, 1932, pp. 336–54.
(6) Turner: *Amer. Journ. of Botany*, vol. ix, 1922, pp. 415–45.

'Züchtungsversuche mit Forstplanzen.' By W. v. Wettstein-Westersheim. *Forstarchiv*, 9 Jahrgang. Heft 8, 15 April 1933.

By A. D. Hopkinson.

HERR WETTSTEIN-WESTERSHEIM in this article on forest tree breeding calls attention to the necessity in Germany of fast-growing broad-leaved species owing to foreign competition in the timber market. For this purpose the genus

Populus at once suggested itself for breeding experiments owing to its rapid growth which enables interesting and useful results to be obtained within a comparatively short period.

With this object in view a number of cross-pollination experiments were conducted with various species of *Populus*. Such crosses as *alba* × *tremula*, *alba* × *canadensis*, *eucalyptus* × *alba*, and *alba* × *pryamidalis* being made.

It is interesting to learn that fertile seed can be produced from flowering shoots cut and kept in water, more particularly when it is considered how exhausting a process seed production is normally. It would scarcely have been expected that a severed shoot could have produced the necessary food-supply to produce a fertile seed.

Although the experiments are as yet only in their initial stages some interesting phenomena have been brought to light. For instance the cross *alba* × *tremula* appears to produce a more useful forest tree than *tremula* × *alba* which points to the importance of having the correct mother tree.

There appears to be considerable scope for further experiment in crossing poplars, and it is to be hoped that this work which involves considerable difficulties, partly owing to the different flowering times of the various species, will be continued and later extended to other genera.

Some work has also been done on the origin of seed in connexion with Scots pine, and it has been already demonstrated that plants raised from the seed of certain trees have a far greater resistance to attacks of Lophodermium than that from others. In this connexion it would be of considerable value if a race of *Pinus strobus* could be produced which was immune to attacks of *Cronartium ribicola*.

Forestry Practice: A Summary of Methods of Establishing Forest Nurseries and Plantations with Advice on other Forestry Questions for Owners and Agents. Forestry Commission Bulletin No. 14. H.M. Stationery Office. Price 2*s*. net.

Review by Thomas Thomson.

THIS Bulletin has been prepared on the suggestion of the English Consultative Committee and gives an account of the methods employed in British forestry which have proved most efficacious in the estates of the Forestry Commission and of private owners. Unlike previous Bulletins of the Commission, it is not an account of scientific investigations or statistical information, and for this reason might perhaps have been better issued in a different format under a title such as 'A Forestry Handbook'.

It starts with 'Nursery Work', and an excellent description of the technique follows on a general discussion of the conditions under which the establishment of a nursery is advisable. In the following section, 'Plantation Work', one of the most interesting parts is that dealing with the establishment of oak crops. The importance of close planting in order to obtain a large number of trees from which to select the finest for growing on is stressed. Planting pure or in strips or patches with larch on the intermediate ground is suggested. The introduction of the larch is designed to reduce the cost by giving an early return from thinnings rather than by cheapening the establishment expenses. Nothing is said about the advisability of introducing beech at a subsequent stage.

With regard to planting in general, the employment of costly and over-careful methods in order to ensure a 100 per cent. survival is deprecated, as well as too meticulous beating up, on the ground that unless deaths occur in groups, a 10 per cent. failure does no permanent harm.

The chapter on thinning begins with a discussion of the subject in general, and notes are afterwards given on the particular treatment of the most important species. Emphasis is laid on the importance of the early thinnings and the fact that, whether remunerative or not, the owner cannot afford to neglect them. In particular it is important to remove 'wolf' trees as soon as possible, as if left too long their removal becomes impossible owing to the gaps they would leave. Tables are given of the suggested number of stems per acre of the different species referred to the mean height of the stand, not to the age.

Consideration is also given to Protection, Utilization, and Financial Questions, and the last part gives a summary of the answer to a questionnaire on forestry matters by a number of members of the Land Agents' Society in different parts of the country.

The bulletin will be very useful to owners and agents because it brings together the results of experience on private estates and in the Commission's own work. The compilers disclaim any intention of laying down rules or prescribing methods which will be universally applicable, or which ought necessarily to supersede well-tried and successful practices in estates, nor do they suggest that prescriptions in a text-book can be an adequate substitute for the advice of an expert on the spot. For those unfamiliar with forestry, however, the book forms a useful guide and even those with experience may find useful suggestions.

'Investigations on the Morphology and Comparative History of Development of Foliar Organs. IV. The Prophyll of *Carya Buckleyi* var. *arkansana*.' By Adriance S. Foster. *American Journal of Botany*, vol. xix, No. 8. October 1932, pp. 710–28; plates l. and li; 11 text figures.

Review by H. Bancroft.

In *Carya Buckleyi* var. *arkansana* Sarg. (the Black hickory) the outermost scale ('prophyll') of axillary buds on normal spur or long shoots completely encloses the inner organs, except for a slit-like opening on the outer side of the bud, near the apex.

The author interprets this prophyll as a bifoliar structure, his interpretation being based upon the following facts and conclusions:

1. The prophyll often possesses two laterally-placed keels, which are regarded as corresponding to the mid-ribs of two individual, but fused, scales.

2. The organs following the prophyll are two medianly placed scales, which may be interpreted as a pair of foliar organs, at right angles to the pair forming the prophyll.

3. There are two laterally placed vein-systems in each prophyll, each system consisting of three strong veins with associated finer veins; the middle, and strongest, member of each trio traverses a lateral keel of the prophyll. Each vein-system is therefore considered to indicate an individual organ, the strongest member in each case being the mid-vein.

4. On vigorous shoots the prophyll may subtend two buds, one opposite each lateral keel.

5. Under conditions of abnormal or vigorous growth, the prophyll may develop into two small, laterally placed, simple, and petiolate leaves, each with three strong veins; the vein-system of each 'leaf' corresponds to a lateral vein-system of the normal prophyll.

6. In the development of the bud the prophyll is initiated by two laterally placed centres of active growth, representing the origins of two foliar organs.

Similar prophyll organization and development are indicated in *C. pecan* Asch. and Gr., *C. ovata* K. Koch, *C. laciniosa* Schn., *C. alba* K. Koch, *C. pallida* Ashe, *C. glabra* Sweet, *C. glabra* var. *megacarpa* Sarg., and *C. ovalis* var. *obovalis* Sarg. The buds of *C. cordiformis* K. Koch, however, possess paired valvate prophylls, joined only at the base.

The conclusion to be drawn from this study, therefore, is that the outermost bud-scale of the hickories represents two very reduced leaves, generally almost entirely fused.

Anatomie de la feuille chez les pins maritimes. Travaux du Laboratoire Forestier de Toulouse, tome i, article xviii, 1932. Pp. 1–18; text figs. 1–4. By V. Fieschi.

Review by H. Bancroft.

ACCEPTING C. E. Duff's conclusions [1] that there are three distinct races of *Pinus maritima* L. (= *Pinus pinaster* Solander), with constant and veritable external characters, Mlle. Fieschi has proceeded to study the comparative anatomy of leaves from trees grown in different areas, in order to determine whether there are constant anatomical differences between the three races which would raise them to the status of distinct species, or, at least, of sub-species.

From an examination of the structure of the leaves at different levels it has been shown that the number of resin-canals in the mesophyll, or 'cortex', at the extreme leaf-base provides an important diagnostic character in '*Pinus maritima*', permitting the separation of two distinct types:

1. An Atlantic type, in which there are always *only* 2 canals: this coincides with Duff's 'Atlantic or Landes race', occurring on the Atlantic coast of southern France and of Portugal.

2. A Mediterranean type, on which there are almost invariably *more than* 2 canals: this type includes Duff's 'Corsican race', and also his third race which is characteristic especially of the Mediterranean region of Southern France. In the Corsican forms Fieschi finds that there are generally from 6 to 10 canals; while in the Mediterranean-French forms there are from 2 to 17, generally from 11 to 14.

This anatomical difference between the two main types is constant, even under different conditions of growth—for example, the native *Pinus maritima* of Narbonne has the 'Mediterranean' canal-number, while the *Pinus maritima* introduced from the Landes conserves the 'Atlantic' canal-number.

Fieschi therefore claims that there are two distinct Linnean species included under *Pinus maritima*: (1) the Atlantic species; (2) the Mediterranean species. In the latter case, since no clear *anatomical* difference can be demonstrated between the Corsican and the Mediterranean-French types Fieschi considers them to be sub-species characterized by their external morphology. Suggestions with regard to the re-naming of these species and sub-species are given by Fieschi and Gaussen in another contribution.[2]

[1] 'Notes on *Pinus pinaster* Soland in Europe, with reference to *Pinus pinaster* var. *Hamiltonii*.' (Report to the Imperial Forestry Institute University of Oxford, 1927); and 'The varieties and geographical forms of *Pinus pinaster* Soland in Europe and South Africa, with notes on the silviculture of the species' (Union of South Africa, British Empire Forestry Conference, Australasia, 1928).

[2] Fieschi, V., et Gaussen, H.: 'Classification des pins maritimes' (*Trav. Lab. For. Toulouse*, tome i, article xix, 1932).

La Classification des Pins maritimes, by Mlle. V. Fieschi and H. Gaussen. *Travaux du Laboratoire forestier de Toulouse*, article XIX, 1932.

Review by J. H. Turner.

THE authors propose a revision of the nomenclature and the readoption of the name *Pinus maritima* strictly for the pine of Gascony and Portugal and a new name, *Pinus mesogeensis*, for the Mediterranean species. *P. maritima* has only two resin-canals at the base of the needle, whilst *P. mesogeensis* generally has more than two, the number varying from 7 to 8 or more. Two more of the latter are described, *P. mesogeensis corteensis* of Corsica and *P. mesogeensis provincialis* of Narbonne and Provence. There are various photographs showing the differences in habit.

The Importance of the Origin of Seed used in Forestry. By H. G. Champion. Indian Forest Records (Silviculture Series), vol. xvii, part v. 1933. Price 5*s*.

Review by the Editor.

ONE of the subjects which has increasingly interested foresters during the present century is the question of origin of seed. This has resulted in the carrying out of many experiments, some organized internationally, and on the accumulation of a large literature. Mr. Champion has attempted a digest of this, primarily for his colleagues in the Indian Forest Service, but it will be of interest to a much wider circle, and we heartily recommend it to our readers.

The subject is dealt with comprehensively as the chapter-titles will indicate: effect of size of seed or fruit; effect of age, size, and dominance of parent tree; inheritance of morphological variations; inheritance of phenological variations; inheritance of physiological variations; inheritance of sports, mutations, &c.; geographical races; altitudinal races; soil races; organization and legislation for authentic seed supplies; selective breeding; hybridization; and co-ordination and interpretation of experimental results. Each of the principal chapters is further subdivided, for example, under inheritance of morphological characters, bole form & branching, bark characters, timber characters, spiral and figured grain, &c., are dealt with.

The data are presented in a systematic and lucid fashion; each chapter opens with some general remarks, the literature on the subject of the chapter or subsection of the chapter is then presented and discussed under continent or sub-continent of origin, and the results summarized.

The value and usefulness of any summary of literature depends primarily on whether it is studied critically or no. Mr. Champion indicates in his statements whether the work under discussion is suggestive only or conclusive. It is realized, of course, that much of the work done to date on the subject of inheritance in forest trees does not reach a very high scientific standard, due principally to the difficulties inherent on such long-lived and late reproducing organisms.

As knowledge in this subject is now advancing quickly, a revision of this Record may be expected in due course. We would suggest that a general discussion on inheritance would be interesting and helpful as an introduction to the discussion of the specialized literature. It is true that this would not be an easy thing to do, because the views of biologists have probably never been more chaotic on the subject than now, but that makes it all the more necessary to the general reader.

One hundred and fifty literature references are cited, and not the least interesting part of the Record is a series of photographs giving Indian examples of the points discussed.

Les Pseudotsuga et leur résistance au froid en France. By F. Flous and H. Gaussen. *Travaux du Laboratoire forestier de Toulouse*, article xx. 1932.

Review by J. H. Turner.

NORMALLY *Pseudotsuga taxifolia* Britt. (*P. Douglassii* Carr.) is hardy in France, but young trees in regions where the ground is unprotected by snow fare badly during cold and sunny weather. In such localities the shallow roots are unable to obtain moisture from the frozen ground and as transpiration continues, the young plants are injured or killed.

Pseudotsuga glauca is more resistant to frost and drought but it is too slow-growing, and M. Auzel has introduced a hardy, quick-growing grey-blue form of *P. glauca*, akin to *P. glauca* var. *caesia*, which has given good results, but it is too early to arrive at definite conclusions and further trial is necessary. If the new variety continues to grow rapidly it may be suitable for afforestation on exposed and acid soils. The authors have made an anatomical study of *Pseudotsuga taxifolia* Britt. and *P. glauca* Mayr which definitely shows these two species to be distinct. The descriptions are accompanied by drawings of the cones, buds, leaves and leaf sections.

NOTICES

On the *Fixation of Atmospheric Nitrogen by Bacteria living symbiotically in Root Nodules of Casuarina equisetifolia.* R. N. Aldrich-Blake. Oxford Forestry Memoirs, Number 14, 1932. Price 3*s.* 6*d.*

THIS memoir presents the results of an investigation carried out by Mr. Aldrich-Blake in collaboration with the silvicultural staff of the Forest Research Institute, Dehra Dun.

It was already known that thirty-five species of *Casuarina* have bacterial root nodules, and that bacteria isolated from nodules of *C. equisetifolia* and *C. Cunninghamiana* fix atmospheric nitrogen in pure culture. While this investigation was in progress another worker showed that infection with crushed nodules could induce nodule formation, but failed to demonstrate the benefit thereof. It remained to be proved, therefore, whether or no *Casuarina* had a nitrogen economy similar to that of leguminous plants. Mr. Aldrich-Blake also wished to determine whether nitrogen increased, either by bacterial activity, or the addition of nitrogenous salts, would depress the relative root-weight in *Casuarina* as in other species investigated. The causal explanation for this effect is discussed by Mr. Aldrich-Blake in a Note on p. 64 of this number.

The investigation was carried out by pot experiments with adequate replications. The treatments were: control plants grown free from bacteria; plants grown with ammonium nitrate; and plants grown in soil inoculated with a mixture of slices of nodules, crushed and mixed with loam. A similar quantity of this inoculum, but sterilized, was also added to the controls, so that they received the same chemical compounds, except thermolabile substances.

The result of the experiments were that the infected plants were seven times the weight of those receiving ammonium nitrate, and about fifty times the weight of the controls. The nitrogen from ammonium nitrate decreased the relative root-weight to a moderate degree, while the greater quantity of the nitrogen obtained from the bacteria reduced it to a fully significant degree. The complete data, fully analysed, are presented tabularly and graphically.

These experiments prove that *Casuarina* may be added to the increasing list of plants which obtain atmospheric nitrogen through symbiotic bacteria. Trees of this genus should be used as hosts for the sandalwood tree, and should be encouraged as soil improvers on sandy equatorial coasts, on which they doubtless owe their natural pioneering ability to their nitrogen economy.

Report of the Forest Products Research Board for the Year 1931. H.M. Stationery Office, London. 1932. Price 3*s.* 6*d.*

THIS publication presents in summary form the progress made in the many fields of activity covered by this Board. All those interested in the growing and utilization of timber should read it, because it is impossible in a review to do more than refer to a few points.

Problems associated with working qualities of timber. The Section of Timber Physics has, during the past year, collected the available information on this subject, and has mapped out the general lines along which research may be expected to prove most useful. The results have been given in Bulletin No. 13. This bulletin discusses the general principles of cutting, rotating cutters, saws, and concludes with a plan of suggested experimental work. In the report reference is made to methods of measuring 'finish', both by frictional resistance, and the reflecting power, or gloss of, a machined wood surface.

The relations between moisture content of wood and the surrounding hygrometric conditions. 'A study is being made of the equilibrium values of the moisture content in wood corresponding to different temperature and humidity conditions of the surrounding air. It is found that, for any hygrometric state of the air, the value of the equilibrium content differs considerably among species.'

Kiln-seasoning experiments. Kiln experiments on a large scale have been made on large numbers of home-grown species. Better results have been obtained with oak, but it is considered that a combination of preliminary air-seasoning, followed by treatment in the kiln, may be a more practical method of dealing with this and certain other hardwoods. Ash seasoned satisfactorily, except for a somewhat excessive cupping which, however, was removed by a reconditioning treatment. The softwoods presented little difficulty.

Reconditioning. This is a term which has been applied to a treatment consisting essentially of warming the timber, which was first dried to a moisture content of 15 per cent., to 210° F. in saturated air. The method has been successfully applied to elm, ash, &c., which showed collapse or similar defect.

The preservative treatment of wood. 'Investigations into the effect of the structure of wood on its preservative treatment with antiseptics have been initiated.'

Timber insect survey. The entomological work of the Laboratory during 1931 has shown that, as hitherto, the insects which cause most trouble in the hardwood timber and allied trades in this country are still the *Lyctus* Powder-post beetles. An American species *L. cavicollis*, not hitherto found in this country, has been found on English ash.

Death-watch beetle. The work on this important species is described.

Dry rot investigations. The experimental work in progress on the specially constructed building to test good and bad construction is described.

The chemistry of decay. Research on the chemistry of the white rots of wood has been continued, and the respective effects on wood substance of *Armillaria mellea*, *Polyporus hispidus*, *Stereum hirsutum*, and *Trametes pini* have been investigated. The general

conclusion from the work on white rots is that these do not all attack wood in the same manner.

The advisory work done by the Laboratory, and the work for the Empire overseas are also described.

As usual the Report is well illustrated, and it presents an imposing array of research work in progress.

Forestry Commission Report on Census of Production of Home-grown Timber 1930. H.M. Stationery Office, London. 1932. Price 3*d.*

THIS Report is supplementary to the Census of Production 1924. A comparison of the 1924 and 1930 figures shows that in Great Britain production decreased by 14·2 per cent., and value by 11·6 per cent. The production for 1930 was: England 26,438,500 cubic feet, Scotland 16,438,100 cubic feet, and Wales 5,179,900 cubic feet. In Wales production increased, but the Scottish figure was 25·7 per cent. less. The prices per cubic foot obtained were higher in England than in Scotland and Wales. The averages for sawmill sizes for Great Britain were: Scots pine 5½*d.*, larch 11½*d.*, spruce 5½*d.*, Douglas fir 7½*d.*, oak 1*s.* 3*d.*, beech 9*d.*, ash 1*s.* 9*d.*, and elm 7½*d.* The production of softwoods was 2·7 per cent. of the total consumption, and of hardwood 20·4 per cent.

The Imperial Forestry Institute, University of Oxford. Eighth Annual Report 1931–2.

THE Report describes the various activities of the Institute. There were 22 students compared with 32, the average of the previous five years. In systematic forest botany, in addition to a large number of tree identifications, special work was done by Dr. J. Burtt-Davy on the Cricket Bat Willow, and on cultivated poplars. In the structure and properties of wood, descriptive work was continued under Dr. L. Chalk. Determinations were made of wood from the shrines outside the sarcophagus of Tut-ankh-amen. Two woods appear to have been used, true cedar (*Cedrus sp.*), and a species of *Zizyphus*, closely resembling *Z. mucronata* (the *sidder* of the Sudan). In entomology research work on *Ernobius* and *Molorchus* was continued by Dr. R. N. Chrystal. In the mycology section research was conducted under Mr. W. R. Day on frost damage. Infection experiments with larch canker and *Phomopsis* on Douglas fir, control of leaf-cast on larch, Dutch Elm Disease, heart-rot of oak, ink disease of Sweet chestnut and die-back of beech, poplar canker, and damping-off of seedlings. A Section of Royal Engineers has been formed under the command of Captain A. H. Lloyd, M.C., and in future Institute students will be able to carry out engineering training with this unit in such branches as are useful for forestry.

The Preservative Treatment of Estate and Farm Timber. By R. C. B. GARDNER. The British Wood Preserving Association, Circular No. 1, 1933. Price 6*d.*

THIS is a lucid and well-illustrated description of preservative treatments which can be carried out with relatively simple apparatus. It should increase wood preservation throughout the countryside, and save much waste of time and money. It is recommended to all readers.

EXPERIMENTS ON THE AGES AND TYPES OF NURSERY STOCK FOR PLANTING OUT

BY W. H. GUILLEBAUD

(Chief Research Officer, the Forestry Commission)

INTRODUCTION.

THE decision whether, on a given soil, seedlings or transplants of a given species should be used for planting depends upon a number of considerations of which the characteristics of the species, the quality and size of the plants available, the nature of the planting site, and the relative cost of the plants are perhaps the chief. It is well known that 1- and 2-year-old seedlings of most of the common forest trees cost only about one-third as much to produce as 3- or 4-year-old transplants, hence the use of seedlings would be attractive, wherever conditions permit, provided that their subsequent growth is not markedly inferior to that of transplants.

When the major decision has been made, there still remains a number of further alternatives to be considered; among seedlings there is a choice between 1-, 2-, and 3-year seedlings (1+0, 2+0, and 3+0), while there is a still wider range of transplant types theoretically at the disposal of the planter, for example, 1+1, 2+1, 1+1+1, 1+2, 2+2,[1] &c. There has always been much difference of opinion among foresters as to the relative merits of the different types of plants, and the question is one on which it is not easy to get reliable evidence.

There are several methods of approach to the problem of raising the different types of plants for comparison.

(1) The several age-types can be obtained from a variety of sources, and the plants put out in adjacent field plots suitably replicated. This method has the great drawback of comparing plants which may have been raised in different nurseries, and from seed of different dates of collection, and possibly not even from the same climatic zone.

It is known that these factors can lead to considerable errors owing to the inherent differences in vigour and rates of growth of plants of different seed provenance.

(2) Plants can be raised from one lot of seed, part of the seed being held over from year to year until the full range of ages is available, and all the types then planted out in the last year.

This gets over the drawback of different origins, but it is possible that the seed may suffer owing to storage, and that sown in the last year may produce plants which are less vigorous than when the seed was fresh.

[1] A 1+1 plant is a plant which has been lifted from the seed-bed at the end of the first year, and has spent the second year in nursery lines; in other words it is a 2-year-old once-transplanted plant. A 1+1+1 plant is 3 years old and has been twice transplanted; similarly a 2+1 plant is a 3-year-old plant which has spent 2 years in the seed-bed and 1 year in nursery lines.

(3) One lot of seed is used. In the first year some of the 1-year seedlings are planted out, others lined out to provide 1+1 transplants, and the rest left to grow in the beds; in the second year 2-year seedlings and 1+1 transplants are planted out and 2-year seedlings lined out; in the third year the following types can be planted out: 3+0, 1+2, 1+1+1, 2+1; and the fourth year would complete the experiment with 2+2, 2+1+1, and other 4-year-old types.

The obvious drawback to this method is that the planting is spread over four successive years, so that the plants of the different ages are not directly comparable. On the other hand, it does provide definite information as to the relative merits of different types of plants of the same age, and, in course of time, when the effect of difference in date of planting becomes less important, some conclusions may legitimately be drawn as to relative growth in the field.

THE EXPERIMENTS.

A number of experiments have been carried out by the Forestry Commission with Scots pine at Teindland Forest near Elgin in Morayshire, at Edensmuir in Fifeshire, and with Norway spruce and Sitka spruce at Inchnacardoch Forest near Fort Augustus in Inverness-shire. The experiments were planned for the most part by Dr. M. L. Anderson, late Forestry Commission Research Officer for Scotland, and have been assessed and much of the data worked up by Mr. J. A. B. Macdonald, the present Research Officer.

Acknowledgements are due to the Forestry Commissioners for permission to publish the results.

A. *Scots pine.*

Four experiments were laid down at Teindland and one at Edensmuir in the planting years P. 26 to P. 28 (P. 26 covers the period autumn 1925 to autumn 1926). The ages and types employed and the method of producing these (see above) were as follows:

Method 1. Plants raised from different seed lots and all put out in the same year.

Teindland No. 17; P. 27. Ages and Types.	*Edensmuir No. 1; P. 26. Ages and Types.*
1+0	2+0
½+½*	
2+0	2+1
2+1	2+2
2+1+1	
2+2	

*Note.—The ½+½ in experiment 17 and the ½+1½ in experiment 31 are plants which were pricked out half-way through the first growing season; thus the ½+½ have spent 3 months in the seed-bed and about 8 months in the lines; the ½+1½ have spent 3 months in the seed-bed and about 20 months in the lines.

Method 2. Seed of one lot was used, the seed being held over from year to year, until all the ages and types were available. All plants were put out in the same year.

Teindland No. 31; P. 28.
Ages and Types.

1+0

2+0
1+1
$\frac{1}{2}+1\frac{1}{2}$

2+1

Method 3. Plants were raised from one seed lot sown on one date, the plants being put out in successive years as the various ages and types became available.

Teindland No. 14; P. 26. *Ages and Types.*	*Teindland No. 15; P. 27.* *Ages and Types.*
1+0	1+0
2+0	2+0
1+1	1+1
1+1+1	1+1+1
1+2	1+2
2+1	2+1
1+1+2	1+1+2
1+2+1	1+2+1
2+2+1	2+1+1
2+2	2+2

Sites. Experiment 17 at Teindland was established on poor Calluna moorland at 750 feet elevation on a moderately exposed site with a northerly aspect. The soil is a heavily leached boulder till. Vegetation, *Calluna* with some *Scirpus*, Cotton-grass, and *Erica Tetralix*. Nos. 14 and 15 are situated on a gravelly sand at about 500 feet elevation, upland grasses and gorse forming the bulk of the vegetation. No. 31 is on a sandy loam of glacial origin, the vegetation being heather and upland grasses. These last three experiments are on fairly good pine sites. The Edensmuir experiment is on a level and sheltered site near sea-level, and the soil a sandy loam of glacial origin. The ground formerly carried a crop of Scots pine, but it now supports a thick herbage of grass.

Lay-out. Experiment 17 was laid out in randomized blocks with five replications of each age and type and 150 plants in each unit plot.

Experiments 14 and 15 were laid out on the A B C D, A B C D, &c., plan, with single plants of each type; unfortunately the arrangement was such as to make most of the A plants run in a single diagonal row, and the same with the B, C, and D, &c., plants. The actual effect was to have only two replications

of each age and type with the numbers varying in the two replications. The number of plants of each age and type put out in each of these experiments was 100.

In experiment 31 at Teindland the unit plot contained 100 plants and there were four replications in randomized blocks.

At Edensmuir each of the three ages and types was planted in a single block of 1 acre in extent. In a fourth acre-block the ages and types were planted in single rows on an A B C, A B C arrangement.

Results. The losses, recorded 4 to 6 years after planting, are shown below:

TABLE I

No. 17. P. 26.		*No. 1. P. 26.*	
Ages and Types.	*Losses per cent.*	*Ages and Types.*	*Losses per cent.*
1+0	23	2+0	43
½+½	24	2+1	11
2+0	18	2+2	8
2+1	6		
2+1+1	6		
2+2	8		

No. 31. P. 28.		*No. 14. P. 26.*		*No. 15. P. 27.*	
Ages and Types.	*Losses per cent.*	*Ages and Types.*	*Losses per cent.*	*Ages and Types.*	*Losses per cent.*
1+0	29	1+0	39	1+0	24
2+0	56	2+0	49	2+0	11
1+1	16	1+1	5	1+1	37
½+1½	7				
		1+1+1	5	1+1+1	3
2+1	8	1+2	5	1+2	23
		2+1	13	2+1	35
		1+1+2	53	1+1+2	10
		1+2+1	13	1+2+1	11
		2+1+1	13	2+1+1	12
		2+2	45	2+2	10

The small number of plants used in experiments 14 and 15 rule these out for serious consideration in respect of losses. As far as the other three experiments are concerned, the 1-year and still more the 2-year seedlings sustained heavy losses, while there is little to choose between the transplants, all of which show a satisfactorily high proportion of established plants.

Growth after Planting out. It will be convenient to consider the experiments

in two groups in the first of which all the plants were put out in the same year and in the second planting was done in successive years.

(1) The following table records in inches the mean height at the end of the 1932 growing season and also the mean length of the leading shoots of that year for the experiments in group 1.

TABLE II

No. 17. P. 27.			*No. 31. P. 28.*			*No. 1. P. 26.*		
Ages and Types.	*Height.*	*Shoot.*	*Ages and Types.*	*Height.*	*Shoot.*	*Ages and Types.*	*Height.*	*Shoot.*
1+0	13·5	2·7	1+0	14·0	3·9	2+0	37·5	8·1
½+1½	12·5	2·8						
			2+0	15·0	3·4	2+1	49·0	10·7
2+0	13·5	2·6	1+1	21·0	5·0			
			½+1½	25·5	5·6	2+2	59·0	11·6
2+1	21·0	3·8						
			2+1	20·5	4·5			
2+1+1	18·0	3·2						
2+2	21·0	3·4						

As already indicated, plants of different seed origin were used in experiment 17 at Teindland and 1 at Edensmuir, while all the plants in experiment 31 have the same seed origin. The general trend, however, of the results is the same in all three experiments; the seedlings have made considerably less progress than the transplants and are still growing at a slower rate. The behaviour of the three lots of 2-year-old plants in 31 P. 28 is interesting; the normally transplanted 1+1 plants and the pricked-out ½+1½ plants have grown markedly better than the 2-year seedlings.

(2) In the remaining experiments 14 and 15 at Teindland the plants were derived from the same seed lot, but there is a difference of a year in the date of planting each successive age of nursery stock. The chief interest of these experiments lies in the comparison of different types of plant of the same nursery age, i.e. 2+0 compared with 1+1 and 1+2 with 2+1 and with 1+1+1 plants.

The present (end of 1932) mean heights and shoot-growths (in inches) are given in Table III below.

The 1-year seedlings which have been planted from 1 to 3 years longer than the rest of the types are now growing well in both experiments. In 15 P. 27 they are the tallest of the series, but in 14 P. 26 they have been outstripped by the 1+1 although these were planted a year later. The 2-year seedlings did well in 15 P. 27 and very badly in 14 P. 26. Results with the 3-year-old transplants, 1+2, 2+1, and 1+1+1, are distinctly conflicting. In 14 P. 26 the 1+2 are the best and the 2+1 and 1+1+1 are much on a level. In 15 P. 27, on the other hand, the 1+1+1 are definitely superior to the other types. The different types of 4-year-old transplants do not differ significantly

among themselves; as compared with the 3-year-old plants, the extra year in the nursery may have more or less balanced the loss of a year in the forest.

TABLE III

No. 14. P. 26.				*No. 15. P. 27.*			
Ages and Types.	*No. of years planted.*	*Mean Height.* in.	*Mean Leading Shoot.* in.	*Ages and Types.*	*No. of years planted.*	*Mean Height.* in.	*Mean Leading Shoot.* in.
1+0	7	32	7·8	1+0	6	27	6·5
2+0	6	19	5·6	2+0	5	26	6·7
1+1	6	36	8·6	1+1	5	22	6·1
1+1+1	5	23	5·4	1+1+1	4	25	7·0
1+2	5	27·5	6·7	1+2	4	15	4·4
2+1	5	23	6·5	2+1	4	15	4·5
1+1+2	4	25	2·7	1+2+1	3	17	4·1
1+2+1	4	24	4·0	2+1+1	3	15	4·0
2+1+1	4	20·5	4·3				
2+2	4	21·5	4·4				

The mean shoot growths from year to year after the second year from planting have been worked out for the two Teindland experiments 14 P. 26 and 15 P. 27. See Table IV.

The tables do not show any very clear trend especially when the two experiments are compared together. There would seem to be a tendency for the 2-year and 3-year-old plants to recover from the check due to planting more quickly than either the 1-year seedlings or the 4-year-old transplants. On the whole the 1+1 plants have given the most consistent performance by putting on shoots of over 6 inches in length in the fourth year in experiment 15 and in the fifth year in experiment 14.

Discussion of Results. Different ages and types of Scots pine have been planted out in four experimental series and three different methods of carrying out the work have been followed. Losses have been relatively high in the 1- and 2-year seedlings, moderate in the 1+1 transplants, and low in most of the remaining types.

As regards rate of growth, the seedlings are definitely slower in starting than the transplants but ultimately, as is apparent from experiments 14 and 15 at Teindland, may make quite satisfactory growth. The 1+1 transplants on the whole have done well; they are superior to the 2-year seedlings and at least as good as the 2+1 plants. Only in the Edensmuir experiment have the 4-year-old plants a definite superiority over the younger transplants, but the difference in seed origin may be a complicating factor here.

As far as the types of ground on which these experiments have been carried out are concerned, it is concluded that the present practice of relying mainly

TABLE IV

Ages and Types.	2nd	3rd	4th	5th	6th	7th years after planting.
	No. 14. P. 26.					
	Shoot growth in inches in the					
1+0	2·6	4·5	4·5	3·8	7·2	7·8
2+0	3·2	2·6	2·5	4·8	5·6	..
1+1	1·3	4·4	4·4	9·6	8·6	..
1+1+1	2·8	1·8	4·1	5·4	..	..
1+2	2·1	3·0	6·7	6·7	..	..
2+1	2·3	2·7	5·6	6·5	..	..
1+1+2	1·1	2·3	2·7	..	..	..
1+2+1	1·3	3·2	4·0	..	..	..
2+1+1	1·4	3·3	4·2	..	..	..
2+2	1·1	3·3	4·4	..	..	..
	No. 15. P. 27.					
1+0	2·8	4·3	4·0	6·6	6·5	..
2+0	3·7	4·3	7·3	6·6	..	..
1+1	2·3	3·3	6·6	6·1	..	..
1+1+1	2·2	6·4	7·0	..	..	..
1+2	2·0	4·0	4·4	..	..	..
2+1	1·9	4·1	4·5	..	..	..
1+2+1	1·9	4·0	..	..	..	..
2+1+1	2·6	4·0	..	..	..	..

on 2+1 plants of Scots pine is justified. Where the weed growth is not too heavy the use of 1+1 stock is to be recommended on the score of lower cost.

B. *The Spruces.*

Two experiments on exactly parallel lines were carried out with Norway spruce and Sitka spruce respectively at Inchnacardoch in P. 26. The method adopted was the same as for the Scots pine experiments 14 and 15 at Teindland, i.e. the same seed lot was used, the plants being put out in successive years; the same lay-out also was adopted. The site was a moderately sheltered gentle slope at a low elevation, the soil a good moist loam, and the vegetation bracken, grass, and herbs.

The actual failures recorded to date are shown in Table V.

Unfortunately, little weight can be attached to these figures partly because only 100 plants of each age and type were put out, and partly in view of rabbit damage which affected especially the 1- and 2-year-old plants. It may be doubted if any of the apparent differences between the losses in the 3- and

TABLE V

Ages and Types.	*No. of years planted.*	*Loss per cent.* *Sitka spruce.*	*Norway spruce.*
1+0	7	56	60
2+0	6	22	48
1+1	6	46	38
1+1+1	5	16	34
1+2	5	8	16
2+1	5	24	32
1+1+2	4	6	20
1+2+1	4	10	10
2+1+1	4	10	12
2+2	4	16	28

4-year-old plants are really significant, but the relative success of the 1+2 plants of both species is perhaps worth noting.

The data relating to height growth are relatively much more reliable than those relating to losses, damaged plants were excluded in the assessments, and statistical analysis indicated that the variations about the means were satisfactorily low.

Table VI shows the mean length of the leading shoots of each type of plant in the second and subsequent years after planting.

The data indicate that in both species there is a fairly definite relation between the rate of growth after planting and the age of the nursery stock used. It took the 1-year seedlings 6 years, the 2-year plants 4 years, the 3-year transplants 3 years, and the 4-year transplants 2 years after planting out before they began to put on comparatively strong shoots. The usual check period is apparent in the short length of the shoots in the second year after planting. Only in the 3- and 4-year-old plants of Sitka spruce is there already evidence that the plants are beginning to recover in the second year after planting.

Differences within the several types of nursery stock of the same age are not sharply marked, but there is an indication in both species of better growth in those plants which have spent two years in the transplant lines. The superiority is most marked in the case of 1+2 Norway spruce which put on a total of 24·3 inches from the second to the fifth year after planting, as compared with 13·5 and 14·6 inches put on by the 1+1+1 and 2+1 plants respectively.

The greater rate of growth of Sitka spruce as compared with Norway spruce is apparent from the tables.

A further point of interest arises from the consideration of the total heights attained by the several ages and types since planting out. The data are contained in Table VII.

Having regard to the standard errors attached to certain of the means it is doubtful if the observed differences between the heights of the several ages

TABLE VI

Ages and Types.	2nd	3rd	4th	5th	6th	7th years after planting.
	Sitka spruce. Shoot growth in inches in the					
1+0	1·0	2·3	4·0	3·9	4·3	13·0
2+0	1·6	3·7	5·2	10·6	9·7	..
1+1	1·6	4·8	4·1	10·8	9·6	..
1+1+1	3·8	5·6	14·2	14·5	..	..
1+2	3·8	5·6	15·0	13·8	..	..
2+1	3·4	5·7	13·6	13·3	..	..
1+1+2	4·6	11·1	11·5	..	..	..
1+2+1	3·1	11·7	13·8	..	..	..
2+1+1	4.3	10·6	11·8	..	..	..
2+2	2.5	13·7	15·1	..	..	..
			Norway spruce.			
1+0	0·3	1·1	1·1	2·5	2·3	5·8
2+0	1·4	1·6	2·9	6·2	6·8	..
1+1	1·7	1·5	3·1	6·7	6·7	..
1+1+1	1·2	1·2	5·3	5·8	..	..
1+2	2·6	4·5	8·0	9·2	..	..
2+1	1·3	2·1	5·2	6·0	..	..
1+1+2	1·5	6·3	6·8	..	..	..
1+2+1	1·6	7·1	6·9	..	..	..
2+1+1	2·6	7·1	6·9	..	..	..
2+2	2·1	7·7	7·5	..	..	..

TABLE VII. *Total height in inches of the plants of each age and type at the end of the 1932 growing season.*

Ages and Types.	No. of years planted.	Total Height (inches). Sitka spruce.	Norway spruce.
1+0	7	39± 5·4	18±1·7
2+0	6	36± 0·6	23±1·3
1+1	6	35±10·9	21±1·8
1+1+1	5	49	18
1+2	5	51± 3·6	29±1·6
2+1	5	42± 4·1	19±1·0
1+1+2	4	38	22
1+2+1	4	40	21
2+1+1	4	37	22
2+2	4	42	24

and types of Sitka spruce are significant. The more rapid development in the field of the older transplants roughly balances the longer period spent there by the younger plants. Much the same holds good for Norway spruce except for the outstanding, and significantly better, growth of the 1+2 transplants of that species.

A third experiment, dealing with the age and type of Sitka spruce, was carried out in the planting year P. 28 at Inchnacardoch. The experiment was situated on a deep basin peat of the *Calluna-Scirpus* type. Four types of plants were used: 2+0, 3+0, 2+1, and 2+2. The unit plot consisted of 81 plants, and each type was replicated four times in a Latin Square arrangement. The planting was carried out on turfs, 2 ounces of basic slag and 12 ounces of mineral soil being mixed into the peat in each turf.

The plants were of different nursery origin and from different seed lots, although the general origin (Queen Charlotte Islands) is believed to have been the same. All the plants were put out in P. 28.

Failures were low in all types, i.e. under 1 per cent. in the 2+0, 2+1, and 2+2, and 6 per cent. in the 3+0 seedlings.

The shoot development is set out in Table VIII.

TABLE VIII

Ages and Types.	*Shoot growth in inches in the*			
	2nd	*3rd*	*4th*	*5th years after planting.*
2+0	1·8	2·4	2·7	2·2
3+0	2·2	4·1	5·0	3·6
2+1	2·2	4·4	4·2	2·7
2+2	2·4	5·2	3·6	3·2

The poor quality of the planting site is responsible for the relatively slow growth of all types of plant. The slight fall-off in rate of growth in the fifth year after planting is probably due to exhaustion of the manure applied. While there is little to choose between the growth of the 3- and 4-year-old plants, these have done appreciably better than the 2-year seedlings.

DISCUSSION OF RESULTS.

It must be admitted that the three experiments on the ages and types of Sitka spruce and Norway spruce do not go very far towards solving the problem as to the relative value of different ages and types of nursery stock for planting under given conditions. The experimental data as to the relative losses in planting out are admittedly of restricted application, but during the past two years extensive trials with 2-year seedlings in comparison with transplants of both spruces have been carried out by the Forestry Commission. These have shown conclusively that seedlings can be used successfully, i.e. with very few failures after planting, if attention is paid to the following points: (1) avoidance

of exposed or poor sites; (2) rejection of weakly seedlings; and (3) adequate care in packing and handling the plants to prevent either over-heating or any drying-out of the roots. These field trials have not been established long enough to provide reliable evidence as to the rate of growth of the seedlings, but in course of time much useful data should be available.

The evidence from the experiments that seedlings take longer to recover from the shock of planting than transplants must militate against their use on sites where the vegetation is very strong, e.g. rushes or tussocky *Molinia*. The relatively good results obtained from the 1+2 transplants suggest that this type of 3-year-old plant deserves more extensive use in future. On the other hand, owing to their small size, 1-year spruce seedlings are difficult to line out and the proportion of failures is often high. If, by an advance in nursery technique, the size and quality of 1-year spruce seedlings can be improved this difficulty might be overcome.

In conclusion there is something to be said on the experimental difficulties of the investigation.

It is felt that the results obtained from these experiments are rather meagre having regard to the time and trouble spent over them. Three different experimental methods have been employed in the course of the work, and none of these can be regarded as wholly satisfactory. The chief problem is to eliminate the sources of error involved in the use of plants of different seed origin, but it is difficult to do this without introducing other important sources of error. In the case of such species as Scots pine and European larch, of which native stands are available, the difficulty could perhaps best be met by the collection in successive years of seed from the same stands, or better from the same individual trees. This would be more difficult to arrange in the case of other species, such as the spruces, the seed of which has to be imported into this country.

The work as a whole illustrates the great amount of care and attention to detail necessary in planning and carrying out field experiments.

SUMMARY.

(1) Seven experiments on ages and types of nursery stock for planting out were carried out in the years 1926 to 1929. Of these, four dealt with Scots pine, two with Sitka spruce, and one with Norway spruce.

(2) Three methods of obtaining the necessary range of ages and types for comparison are discussed, and examples of each method are to be found among the experiments.

(3) Brief descriptions are given of the sites on which the various experiments were located and tables included, giving the data collected as to losses after planting and subsequent rate of growth.

(4) The Scots pine results were somewhat conflicting, but the general conclusion was in favour of once-transplanted stock (1+1 or 2+1) as compared with seedlings or older transplants.

(5) The experiments on Norway spruce and Sitka spruce, planted on a good

site at Inchnacardoch, revealed a definite relation between the age of the nursery stock at the time of planting and the subsequent development of the plants. The check resulting from planting out in the forest was overcome quickest by the 4-year-old plants, 3-year plants took a year longer to recover, while the 1-year seedlings were the slowest of the series to make vigorous growth. The year in which recovery took place was marked in each case by a pronounced increase (of the order of 100 per cent.) in the length of the leading shoot as compared with that of the previous year.

One-year 2-year transplants of Norway spruce were appreciably more vigorous than other types of 3-year-old plants, but there was no corresponding difference in the case of the 3-year-old Sitka spruce transplants.

OAK WOODLANDS ON CLAY SOILS IN SOUTH-WESTERN ENGLAND AND SCARCITY OF NATURAL REGENERATION OF OAK

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INTRODUCTION.

MANY of the woods on clay soils in south-western England are composed of pedunculate oak (*Quercus robur*), generally with an understory of hazel (*Corylus Avellana*). Natural regeneration of oak in these woods is sparse in some places and lacking in others. Ash comes in freely in many places. These woods can be renewed, therefore, only by planting or sowing, unless ash is desired. As oak plantations are expensive and the growth is rather slow, these woods, after cutting, are being replaced by coniferous plantations, or allowed to revert to ash. This is unfortunate for two reasons: first, a certain amount of oak is needed, and if not grown must be imported; secondly, an oak wood, with its associated vegetation, is a better cover for game than a plantation of conifers; hence it gives a higher value to the shooting rights. It appears worth while, therefore, to try to find out something of the causes for the scarcity of natural regeneration of oak. With this end in view a simple experiment was carried out in an oak-ash-hazel wood about 4 miles south of Taunton.[1]

GENERAL ENVIRONMENT.

Climate.

Temperature. The climate of south-western England is mild, with a relatively narrow range of temperature between summer and winter, or day and night. Average temperatures have therefore some meaning in biological studies, unlike some regions where the average may give an entirely misleading impression because it is made up of extremes of high and low temperatures.

In winter it freezes only occasionally, especially when the wind is from the east. The January isotherm of 41° F. (5° C.) passes through south-western England as well as along the Mediterranean coast of France (8, map on p. 25).

In summer the mean temperature of July and August, the warmest months, is only 62° F. (16·6° C.). The maximum only occasionally reaches 85° F. (29·5° C.), rarely 90° F. (32° C.), and is most frequently 80° F. (26·5° C.) or less.

The mean annual temperature is about 51° F. (10·6° C.).

[1] The use of this particular wood for the experiment was made possible through the kindness of Mr. A. E. Newton.

Precipitation.[1] The mean annual precipitation at Trull, about 2 miles from the experimental area, for the 21 years, 1911–31, was 33·26 inches (845 mm.). The lowest year, 1921, was 15·63 inches (397 mm.), and the highest, 1914, was 42·63 inches (1,083 mm.). In general, however, the figures for each year run fairly close to the 21-year mean, or only about 10 or 15 per cent. above or below it. A relatively small proportion of the total is in the form of snow.

The distribution of the rainfall throughout the year is fairly uniform. June is generally the driest month, and September, October, and November are the wettest.

The rate at which the rain falls is of much importance, because a high annual precipitation made up largely of heavy rains which run off rapidly is, other things being equal, less effective than a lower precipitation made up of gentler rains. Here the rains are mostly of the gentler type, and hence are more effective than the amount would indicate.

Another factor to be considered in relation to the precipitation is the temperature. In the absence of high temperatures the amount of precipitation is the equivalent, so far as vegetation is concerned, of a considerably greater amount in regions with hot summers.

Relative Humidity and Evaporation. No figures are available on relative humidity and evaporation for this locality, but it is safe to say that the relative humidity is high and evaporation low. The demands of the plants on the water in the soil is therefore generally not excessive. There are, however, in some years rather long rainless periods when the surface soil becomes very dry. This happened during the course of the present experiment, as will be seen later.

Topography, Geology, and Soils.

The principal topographic features of the part of Somerset in which the experiment was carried out are the Vale of Taunton, from sea-level to about 200 feet (63 m.), and the Blackdown Hills, a plateau from about 800 feet (252 m.) to 1,000 feet (315 m.) in elevation, with a north-facing escarpment. Jutting out of the Blackdown Hills is a minor but distinct table-land which is 500 feet (157 m.) on Pickeridge Hill above the village of Corfe, and slopes gradually to the eastward to 200 feet (63 m.) at Hatch Beauchamp.

The region was not glaciated in the Pleistocene, and hence is characterized by soils formed in place and alluvium.

The geological formation in the Vale of Taunton, from south of the town to the foot of the escarpment, is Keuper Marls, which here form a heavy clay soil, grey on the surface and red below. The plateau of the Blackdown Hills is an impervious clay with flints, but the brow of the slope just below the clay with flints is Greensand. The lower table-land north of and touching the Blackdown Hills is Lower Lias, here made up of beds of bluish limestone alternating with beds of clay. This forms a heavy, grey, clay soil. A band of Rhaetic beds, white lias limestones, separates the lower lias of this table-land from the Keuper Marls of the Taunton Vale. This is overlain by a heavy, grey, clay soil.

[1] Records kindly supplied by Mr. A. E. Newton.

The clay soils from the Keuper Marls, from the Lower Lias, and from the Rhaetic, are calcareous and rather fertile, though the Keuper Marls are said to be deficient in phosphates. All three soils seem to contain abundant nitrogen, judging by the prevalence of the nettle (*Urtica dioica*) (7) in the hedges and fields.

VEGETATION.

General Regional. The vegetation is rather like that immediately to the east, so that Moss's account (6) of the Bath and Bridgwater district gives a good picture of it. Pasture land predominates, and very rich pasture it is. Forests cover only a relatively small proportion of the region, 4·4 per cent. for Somerset (4), though the proportion is larger south of Taunton than in most other parts of the county because of the nearly continuous band along the north slope of the Blackdown Hills. More than half of the forest immediately south of Taunton is of oak and ash with hazel as an understory, described more fully below. Most of the remainder is made up of coniferous plantations, principally larch and pine.

The original vegetation has so completely disappeared that it is very difficult to know what it was like. If we could find this out we would, of course, be in a better position to adapt forestry measures to natural trends, and therefore be more likely to succeed.

Some indication of the natural vegetation may be had from parts of the commons, and, to a certain extent, from grown-up hedges. On Staple Common, about 2 miles south of Staple-Fitzpaine, on the Greensand formation on the north slope of the Blackdown Hills (this part being known as Staple Hill), is a dense natural thicket. This is made up of ash (*Fraxinus excelsior*), oak (*Quercus robur*), and thorn (*Crataegus monogyna*), with some birch (*Betula alba*). The hedges on the clay soils contain a good deal of ash. There are also a few oaks here and there. A good deal of elm (*Ulmus campestris*) occurs in the hedges, and propagates from the roots, reproduction of this tree from seed being lacking or rare. Other prominent species in the varied mixture growing in the hedges are field maple (*Acer campestre*), thorn, sloe (*Prunus spinosa*), black elder (*Sambucus nigra*), privet (*Ligustrum vulgare*), and scattered holly (*Ilex Aquifolium*).

The Oak-Ash-Hazel Forest. Most of the forests on the clay soils in the region around Taunton, apart from the coniferous plantations, are composed principally of pedunculate oak (*Quercus robur*), with varying proportions of ash (*Fraxinus excelsior*) and an understory, not always complete, of hazel (*Corylus Avellana*). It seems best to class all these forests together under the single head of oak-ash-hazel, rather than to classify oak-hazel and ash separately as Moss (6) has done. This is because ash, even where in small amounts, is of such potential importance owing to its abundant reproduction. A pure ash forest can also be recognized. The oak forest grows on the Greensand and other less heavy soils, and is quite distinct from the oak-ash-hazel, or the ash. It does not come within the scope of the present experiment.

The oak-ash-hazel forest is characterized by rather short-boled spreading oaks which have the form of standards over coppice, only there are rather more oaks per acre than in the usual standards over coppice forest on the Continent. The oaks are generally even-aged and probably were planted. They are mostly mature to overmature. The successive ages which should be present in standards over coppice are deficient, though ash is occasionally reserved, and one sometimes finds a younger oak.

Natural regeneration of oak, as already mentioned, is sparse or lacking. Ash reproduction is abundant nearly everywhere on these clay soils. Much of it is nipped off, probably by rabbits, but some of it escapes and comes up. In some places sycamore (*Acer Pseudo-platanus*) establishes itself abundantly in thrifty and rapidly growing groups. The tendency of the oak-ash-hazel woods is for the ash to increase at the expense of the oak, and in some places the ash already equals and even outnumbers the oak.

The hazel understory is almost always present, though there are a few places without it. It may have been planted originally, but it reproduces itself readily from seed as well as from sprouts. It is cut about every 8 or 10 years, because, if left longer, it becomes too large to use for making hurdles. This market is diminishing.

There are some stands, though not many, of oak-high forest. They contain young ash in the openings, and scattered hazel. Although unlike the typical stands just described, the difference is mainly one of form resulting from different silvicultural treatment, so they are classed with the oak-ash-hazel forest.

The under vegetation, both of shrubs and herbs, is luxuriant. There appears to be sufficient light for the herbs and shrubs between the crowns of the oaks and between the hazel clumps, except when the hazel becomes older and forms a more or less continuous canopy. Perhaps the two most prevalent components of the under vegetation, in area covered, are the common ivy (*Hedera Helix*) and blackberry (*Rubus fruticosus* agg.). The ivy occurs almost everywhere, and generally is very abundant, forming mats on the ground and climbing the trunks of the trees. Its climbing ability enables it to escape competition from ground plants; for when it is crowded on the ground it ascends the trees and thus obtains favourable conditions for growth. One of the striking features of these woods is the prevalence of ivy on the tree-trunks. It does a certain amount of damage by weighting down and causing the breakage of saplings. Whether or not it does any harm to the trunk is not known. The blackberry grows as clumps in openings or sometimes as a practically solid mass under the lighter canopies. It does not seem sufficiently dense to be a factor in the absence of oak reproduction, though it may interfere to a certain extent with that of ash.

Among the herbs it is difficult to say that any one is dominant except locally. The common ones are enchanter's night-shade (*Circaea lutetiana*), buttercup (*Ranunculus acris*), celandine (*R. Ficaria*), primrose (*Primula vulgaris*), bluebell (*Hyacinthus nonscriptum*), violet (*Viola sylvatica*), strawberry (*Fragaria vesca*), loosestrife (*Lysimachia nemorum*), St. John's wort (*Hypericum perforatum*),

bugle (*Ajuga reptans*), anemone (*Anemone nemorosa*), dog mercury (*Mercurialis perennis*), vetch (*Vicia cracca*), three veronicas (*Veronica Chamaedrys*, *V. officinale*, and *V. montana*), scattered wood angelica (*Angelica sylvestris*), thistle (*Carduus palustris*), spotted orchid (*Orchis maculata*), and a number of others. Moss (6) gives a list of 157 ground species, and for each species the abundance in each of the three forest associations which he recognizes, the oak, the ash, and the oak-hazel. Probably most of these species, except those confined to the oak, grow in the oak-ash-hazel forest.

The layer of leaf litter often found in broadleaf stands is absent. Owing, probably, to the high lime content of the soil and to favourable moisture conditions, as well as to sufficient warmth in summer, decomposition is rapid. We find, therefore, only the leaves of the previous season among the herbs.

EXPERIMENT.

An experiment was planned to test by very simple methods the influence of certain seed-bed conditions, and of different kinds of animals, on the natural regeneration of oak. Watt (9), studying the natural regeneration of oak in a somewhat different way in other parts of England, found that the seed supply is practically entirely destroyed.

The experiment was carried out in the rather extensive oak-ash-hazel wood which clothes the slope of Pickeridge Hill, east of the village of Corfe, 4 miles south of Taunton. The formation is Rhaetic, and the soil is a grey clay which is very sticky when wet, and becomes hard and cracked when dry. The slope faces west, is steep near the top, and rather gentle at the base. The plots were on the lower gentler part of the slope, with a gradient of about 10 per cent., in a small opening, in which, however, there were hazel bushes. The plots were placed between these bushes. The oak is about 80 years old, and the hazel is rather open; it had been cut about 2 years before. The ground vegetation is similar to that described above.

METHODS.

A series of four plots of about 4×3 feet ($1{\cdot}2 \times 0{\cdot}9$ m.) each was laid out. Two seed-bed conditions, the principal ones encountered in nature, were obtained by exposing the mineral soil on one-half of each plot and leaving the natural vegetation intact on the other half. The effect of animals was tested by screening out successively each of the three principal kinds: (1) rabbits; (2) mice and other small rodents; and (3) birds. The control plot was exposed to all animals, just as in other parts of the forest. The three other plots were surrounded by a rabbit-proof enclosure made of the usual $1\frac{1}{2}$-inch (4-cm.) mesh wire screen. One of these plots received no additional protection, so was inaccessible to rabbits but exposed to mice and birds. Around another plot a wire screen of $\frac{3}{8}$-inch (about 1-cm.) mesh was placed and sunk about 4 inches (10 cm.) into the ground, affording protection against rabbits and mice, but not against birds. The fourth plot was also surrounded by $\frac{3}{8}$-inch mesh wire

set in the ground, but in addition was covered with the same kind of wire, so was completely protected.

Each half of each plot was sown with acorns (*Quercus robur*) in the middle of May 1932. In the mineral soil the acorns were covered with only about ¼ inch (6 mm.) of the clay, which at that time was wet and sticky, more like putty than true soil. In the natural vegetation the acorns were merely pushed gently down under the herbaceous cover and leaves. The number of acorns in each condition in each plot was 31, the odd figure being due to the unavoidable necessity of sowing two different lots on account of the difficulty of obtaining acorns. The plots were not watered artificially.

In order to be able to interpret the results in terms of possible germination, a consideration too often neglected, viability tests were started at the same time the plots were established. Boxes were used, containing disintegrated Greensand mixed with about 25 per cent. garden loam, and completely protected by screens. The boxes were watered as needed. The average viability for the two lots of acorns turned out to be 69·4 per cent.

RESULTS.

Seed-bed Conditions. Moisture conditions during the summer of 1932 were such as to afford a good test of the influence of dryness on the seed-bed. There were two drought periods, severe for England.[1] The first was during June, of 25 days with only 0·05 inch (1 mm.) of rain, and the second during August, of 27 days with only 0·46 (12 mm.), most of which came in one day. During both of these periods the mineral-soil parts of the plots became dry and hard, and cracked open, exposing a considerable proportion of the acorns. Even under the natural vegetation, dry periods cause the formation of cracks in these heavy clay soils.[2]

Both seed-bed conditions proved favourable in spite of the droughts. Correcting for viability, the percentages on the completely protected plot were 109·5 in the mineral soil (better than in the viability flats) and 85·7 in the natural vegetation. On the plot exposed only to birds the percentages were 94·7 in the mineral soil, if we deduct the acorns destroyed by birds, and 85·7 in the natural vegetation where no damage was caused by birds.

The seedlings developed normally except for an attack of oak mildew (*Omyces* sp.) which affected those on the mineral soil more than those in the natural vegetation. Curiously enough, in the summer of 1933 those in the natural vegetation were rather heavily mildewed, while those on the mineral soil were only lightly attacked.

Animals. The acorns on the two plots not protected by fine-mesh screens were completely destroyed within about a month, both in the mineral soil and

[1] The record of daily rainfall through the summer was kindly supplied by Mr. A. E. Newton.

[2] These cracks were so numerous as to render it difficult to test the permeability of the soil to water by the Burger method which involves driving a steel cylinder of only 4·44 inches (11·29 cm.) diameter into the soil.

in the natural vegetation, by mice (the bank vole, *Evotomys glareolus*, and possibly also the wood-mouse, *Apodemus sylvaticus* or *A. de Wintonii*).[1]

On the plot exposed to birds, but protected against rabbits and mice, 51·6 per cent. of the acorns in the mineral soil were destroyed by birds, probably wood pigeons. Acorns which were not showing through cracks in the mineral soil were not dug up, and those in the natural vegetation were undisturbed. There were only two raids.

Rabbits did no damage; on the only plot to which they had access they were forestalled by the mice. Of the few natural seedlings that occur, an occasional one is bitten off. Probably in a wood fully stocked with oak regeneration the rabbits would cause a good deal of damage by making a considerable proportion of the seedlings bushy and stunted. However, rabbits are not a primary factor in preventing the establishment of oak. A rabbit-fenced portion of the wood near the plots shows no oak regeneration.

CONCLUSIONS.

The physical conditions of the site, such as soil and moisture conditions, on heavy clays in south-western England are favourable to the natural regeneration of oak. The scarcity of regeneration is due to the destruction of acorns by mice and, to a lesser extent, by birds. Rabbits are not the primary factor in preventing the establishment of oak.

The problem of obtaining natural regeneration, therefore, resolves itself into one of controlling at a reasonable cost the unfavourable biotic factor, the mice, and, as such, falls in the field of the zoologist. It will not be easy to solve. The fluctuations in numbers which occur among all animals in a natural state (1, 2, 3, 5) is extremely important and must be more fully worked out. Control of mice by their natural enemies, such as hawks, owls, and stoats, would reduce the game, and thus impair the owner's enjoyment of his property, or his revenue from leasing the shooting. Incidentally it would probably not be appreciated by his neighbours.

SUMMARY.

Natural regeneration of pedunculate oak (*Quercus robur*) is sparse or lacking in the oak-ash-hazel woods on clay soils in south-western England.

The principal features of the environment are the rather uniform mild temperature, mean annual about 51° F. (10·6° C.), precipitation of 33 inches (840 mm.) per annum well distributed except for occasional dry periods in summer, and high atmospheric humidity.

The oak-ash-hazel forest contains varying proportions of ash, which reproduces rather abundantly, and has a rich under-vegetation in which ivy (*Hedera Helix*) predominates. Decomposition of leaf litter is rapid.

[1] No systematic trapping was done for identification. A bank vole taken in 1933 was kindly named by the Bureau of Animal Population of the University Museum, Oxford. The evidence against the wood-mouse rests on gnawed hazel nuts which Dr. Charles Elton stated in a letter would almost certainly indicate a wood-mouse.

In an experiment with two seed-bed conditions, mineral soil and natural vegetation, on each of four small plots, a control plot, and three screened in different ways to exclude (1) rabbits, (2) rabbits and mice, but not birds, (3) all animals, germination of oak was high in both seed-bed conditions on the plots screened against mice. On the two plots which they could enter, mice destroyed all the acorns within about a month. Birds, probably wood pigeons, destroyed 51·6 per cent. of the acorns in the mineral soil on the plot protected against rabbits and mice but exposed to birds. They did not dig up acorns or disturb those in the natural vegetation.

It is concluded that the physical factors of the site are favourable, and that the scarcity of natural regeneration of oak is due to unfavourable biotic factors, mice and, to a less extent, birds, which destroy the acorns.

The problem of obtaining natural oak regeneration therefore depends on controlling the mice at reasonable cost, and, as such, falls in the field of the zoologist.

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RAY DEVELOPMENT IN THE STERCULIACEAE

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INTRODUCTION.

IT is often very difficult to assess the relative importance of the various features upon which the classification of woods is based, and any classification is bound to be somewhat unsatisfactory until it is possible to trace the development of one form of any particular feature from another, and to decide whether the differences between them are important or not.

In order to understand the relation between different types of ray it is essential to study both the development of the ray cells in the wood and the changes in the cambial initials themselves. The problem is simplified if a large variety of forms can be found in woods which are known to be nearly related, as there is then some justification for assuming that any sequence which can be found is phylogenetic in origin. The Sterculiaceae provide a very suitable group of ray types for study, as they include an unusually wide range of variation in ray structure, and although the present study has been limited to this family, the different methods of ray development which have been investigated occur also in other families. The rays of the Sterculiaceae also include two special features—tile-cells and sheath-cells—which are comparatively uncommon. Tile-cells have already formed the subject of a special study (Chattaway, 3); they occur not only in the Sterculiaceae but also in the nearly related families Bombacaceae and Tiliaceae, and have not yet been observed outside this group. Sheath-cells are rather more common, though by no means widespread, and occur in several other families.

As the stem increases in girth there is a proportional increase in the amount of ray tissue, but this is not merely by growth of the existing rays, which must grow farther and farther apart, but involves the formation of new rays to maintain the distribution of the ray tissue. It has already been shown by Beijer (1) and others that new uniseriate[1] rays arise by the subdivision of the fusiform[2] initials, which normally give rise to the vertical wood elements, and this process is common in the Sterculiaceae; but in this family the spread of ray tissue is also achieved by branching of the large rays. This breaking up of a large ray into smaller ones is brought about by the change of ray initials into fusiform ones. These two methods of spreading the ray tissue involve

[1] Rays are *uniseriate* when they are only one cell wide, and *multiseriate* when they are more than one cell wide tangentially.

[2] *Fusiform initials* are long spindle-shaped cambial cells which give rise to the vertical elements of the secondary wood, as opposed to ray initials which may arise from them by horizontal subdivision, and give rise to the ray tissue.

contradictory processes, in one instance the conversion of fusiform initials to ray initials, in the other the reversion of ray initials to the fusiform condition.

The multiseriate rays which are found in an old stem are not all primary in origin; some of them are derived from the new uniseriate rays, which have subsequently grown considerably in size. This increase in the number of cells is usually the result of the division of the ray initials, but it has been found that this process is augmented in some of the Sterculiaceae by absorbing adjacent fusiform initials into the rays. These new ray initials are at first larger than those of the rest of the ray, and give rise to 'sheath-cells'.

METHODS.

Ray development cannot be studied from the cambium alone, as it is essential to trace the history of individual cambial initials throughout the development of a multiseriate ray from a uniseriate one. Sections of the cambium show any particular cell at one stage only, and are therefore inadequate. The method which has been employed here is similar to that by which Beijer (1), Klinken (5), and Neef (6) studied the structure of stratified cambium, and is a modification of that which Zijlstra (7) employed in his macroscopic study of ray structure.

A wedge of wood, extending if possible from the pith to the cambium, was cut out with each side parallel to the rays, and deep enough to contain the tallest ray. Serial tangential sections were cut at 30 μ; this distance was determined by the radial dimensions of the ray cells, so as to ensure that each ray cell should be represented on at least one section. By following these sections from the pith towards the periphery a picture of the cambium could be obtained as it was at different stages of development. Such a method is only suitable for a study of tissues in which there is little extra-cambial growth, that is to say, in which the individual cells undergo little change in size or shape after their formation from the cambium, and consequently it has limits for the study of vessels or fibres, or of woods without a rather regular arrangement of the tissues. It is, however, entirely suitable for an investigation of ray cells, in which extra-cambial growth is slight, except in a radial direction, and in which the cells retain their shape on tangential sections, and change so slowly in relative position, that any particular ray cell can be traced on serial tangential sections for a long distance through the wood, while any change in shape in the cambial initial is immediately mirrored in the daughter cell. Furthermore, it is easy to distinguish between intra-cambial subdivisions, which affect the initials, and extra-cambial ones, which take place in the daughter cells. The former will be seen in all subsequent daughter cells and will permanently affect the appearance of the ray, while the latter occur only in one cell, and the changes which they cause will be seen only in one section.

INCREASE IN NUMBER OF RAYS.

The primary wood of the Sterculiaceae forms a completely closed ring round the stem, and the primary rays, though they may be high, do not extend for

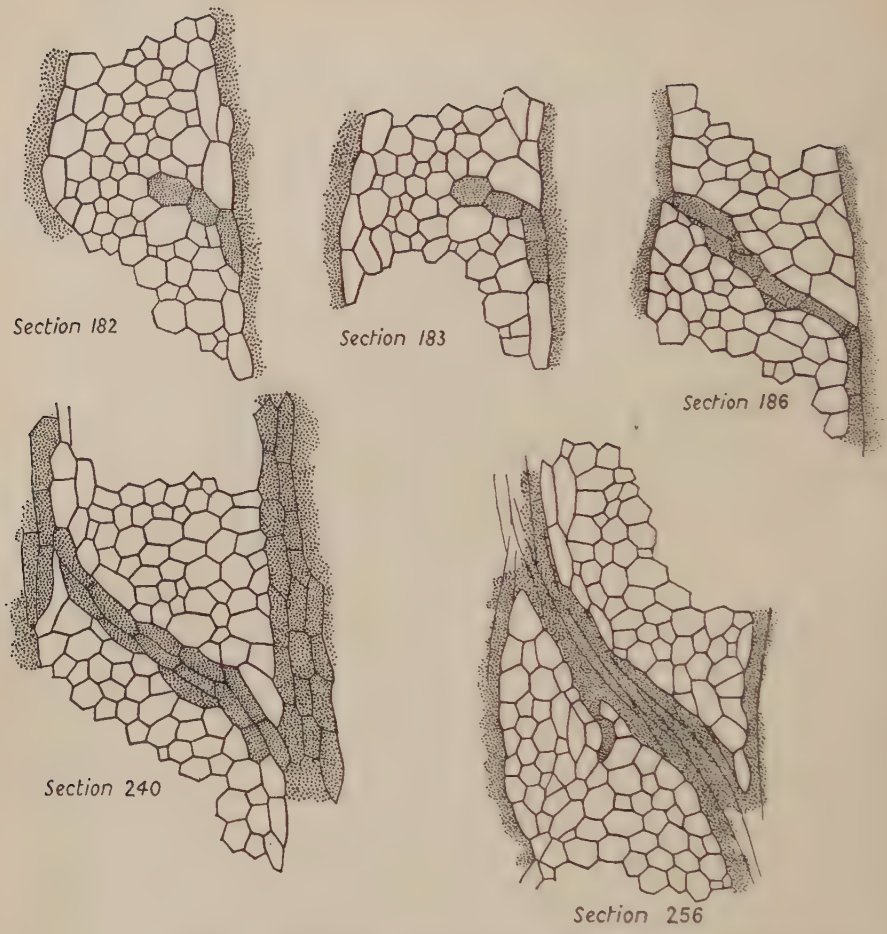
the full internode, and are seldom more than two or three cells wide; though during the formation of the first few rows of secondary cells the primary rays often become much wider, as the result of radial division of the initials.

As the stem increases in girth the primary rays become widely separated, and the need arises for additional ray tissue; this is provided for in two ways. The most usual method is by the formation of new ray initials from fusiform initials, so that a great many small uniseriate rays appear between the larger primary ones. The formation of a new ray initial from a fusiform cambial initial has often been described, but there appears to be very little record in literature of the development of the newly formed uniseriate ray into one of the different types of multiseriate ray. The first stage of ray growth is the transverse division of a fusiform initial; the resultant uniseriate ray at first closely resembles a parenchyma strand, but the cells soon become slightly more rounded, as if distended by contents.

As the usual procedure throughout the family is for only one, or occasionally two or three superposed, fusiform initials to be used up in the formation of the new ray, and as the fusiform initials are storied, it is common to find numerous short uniseriate rays arranged in regular horizontal rows. In many genera these uniseriate rays are very numerous, and they often form such a conspicuous feature of the tangential section of the wood as to give the impression of two distinct ray sizes; as if the uniseriate rays belonged to a different system from the multiseriate ones. In very young stems this is so, and the rays are either primary and multiseriate, or secondary and uniseriate, but this condition is rapidly succeeded by one in which the multiseriate rays are both primary and secondary in origin, and represent all gradations in size from the biseriate condition upwards. If the primary rays are small, and the new rays do not grow very much, an extremely even structure results, and the storied arrangement of all the elements gives distinct ripple-marks to the wood, as in *Mansonia*.

Although this method of spreading the ray tissue evenly through the stem is the most usual, it is not the only one. There are some woods in which uniseriate rays are only sparingly developed, and the spread of ray tissue occurs mainly by the breaking up of the larger rays into smaller ones, which continue to grow and then again subdivide. This splitting up of large rays has already been described by Zijlstra (7) and Jost (4) for the primary rays of the Cupuliferae, for *Aristolochia* and *Clematis*, and for the secondary rays of *Fagus*, but the process has not been described in great detail, and no adequate explanation has been offered for its occurrence. Jost suggests that it occurs by the return of ray initials to the fusiform condition, but gives neither diagrams nor fuller explanation, and later refers to adjacent fusiform initials pushing in between the ray cells by sliding growth.

The process has been followed in different genera of the Sterculiaceae, especially in *Cola togoensis* Engl. and Klause. Details of the changes are given in Text-fig. 1; in sections 182 and 183 the first stages are seen to involve a slight swelling and elongation of the ray cells. They would not be recognizable as



TEXT-FIG. 1. Reversion of ray initials to fusiform initials, causing separation of a large ray into two parts. In section 240 the ray lies among wood parenchyma, in section 256 among fibres. *Cola togoensis* Engl. and Krause. (×85.)

the preliminaries of a split on isolated sections, but can be recognized in serial sections where the later stages can be traced backwards to their inception. In section 186 the line of slightly elongated cells is clearly seen right across the ray; in section 240 the ray is passing through one of the layers of wood parenchyma and is seen to be cut right across by a layer of cells which is almost identical with the parenchyma on the right; in section 256 the ray lies in a region of fibres, and the separating layer is fibrous too. Thus it is clearly seen that the initials which were producing ray cells are now forming alternating bands of fibres and wood parenchyma; this is the normal sequence for fusiform initials. It is quite clear from this diagram that there is no question of adjacent initials pushing in between the ray cells, for the individual cells can be recog-

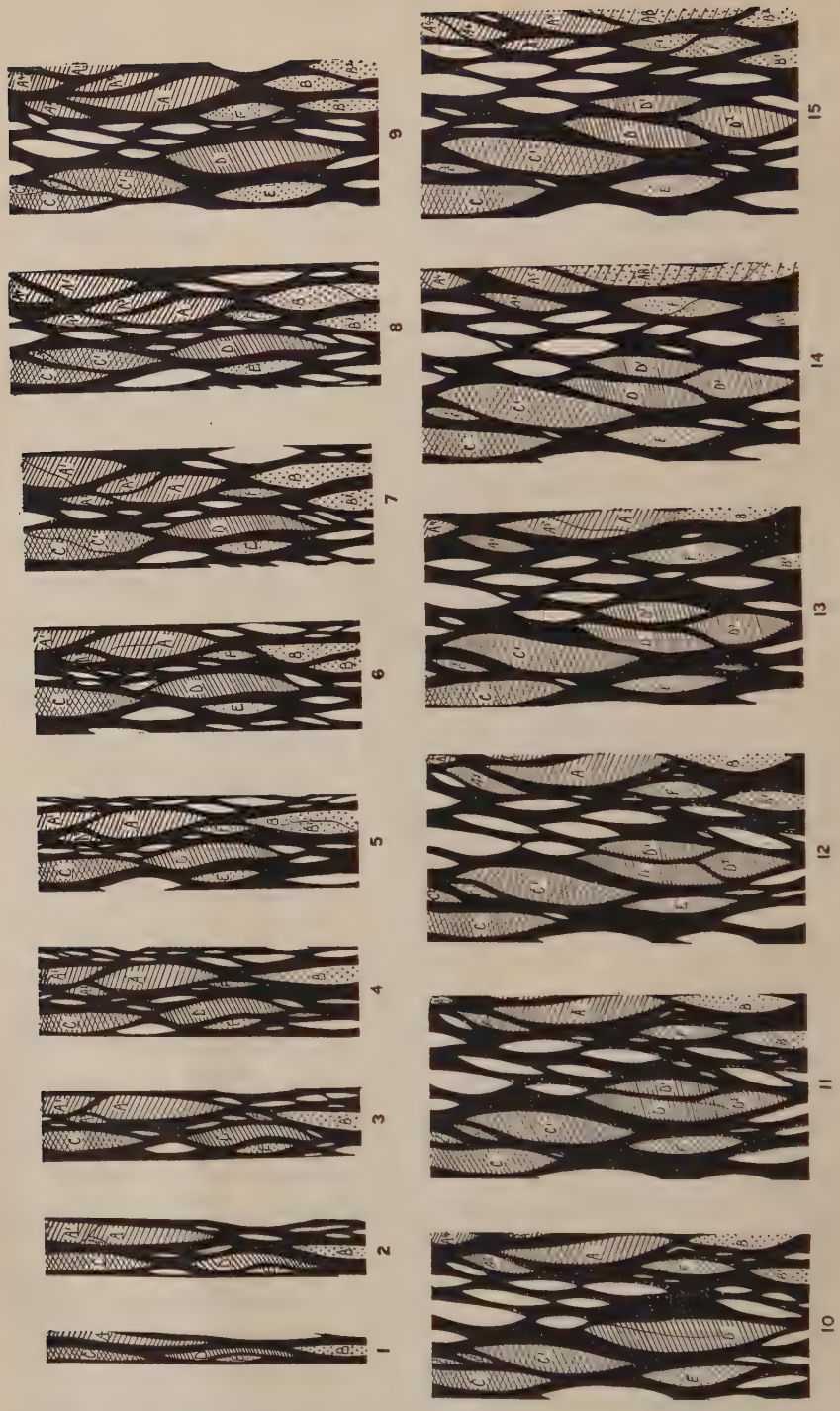
nized in all the figures, and they themselves are changed, not pushed aside by intruding cells.

Similar breaking up of large rays has been observed in species of *Cola*, *Sterculia*, *Eribroma*, *Pterygota*, and *Theobroma*. In *Cola togoensis* Engl. and Klause it occurs with extraordinary frequency, and appears to be the chief way of providing the amount of ray tissue necessitated by the increasing perimeter of the stem, and of disseminating it through the stem. New uniseriate rays, which provide for this increase in other woods, are infrequent. Text-fig. 2 shows a series of diagrams selected from a series of 1,500 sections at intervals through 3 inches of stem, starting from the pith. This wood has moderately numerous primary rays, which often extend some distance vertically, though not through the whole primary internode. Five such rays are shown in 1; they are marked by various signs and cross-hatchings to enable each to be followed in successive sections, and they are marked A–E. At the stage shown in 1, which is near the pith, the wood is not yet storied, but tangential growth is very rapid, and the stories are established within a few hundred microns of the centre of the stem. Number 2 shows the first indication of any splitting, where the changes already described in Text-fig. 4 occurred, and rays A^1 and A^2 are seen to be split off from A; by 5 these three rays are seen to be separated by a considerable mass of ground tissue. In 5, ray B begins to split, and similar splits can be followed in the other rays in succeeding sections. Ray F appears first as a small uniseriate ray in 3; it grows in size till 14, when it undergoes its first split into F and F^1. Ray C splits for the first time in 7; some of the rays derived from it are pushed out of the section by the tangential growth of the wood, and do not appear in the diagrams, but nevertheless by the end of the series ray C can be seen to have given rise to ten rays, and to have spread through a considerable tangential area of the wood.

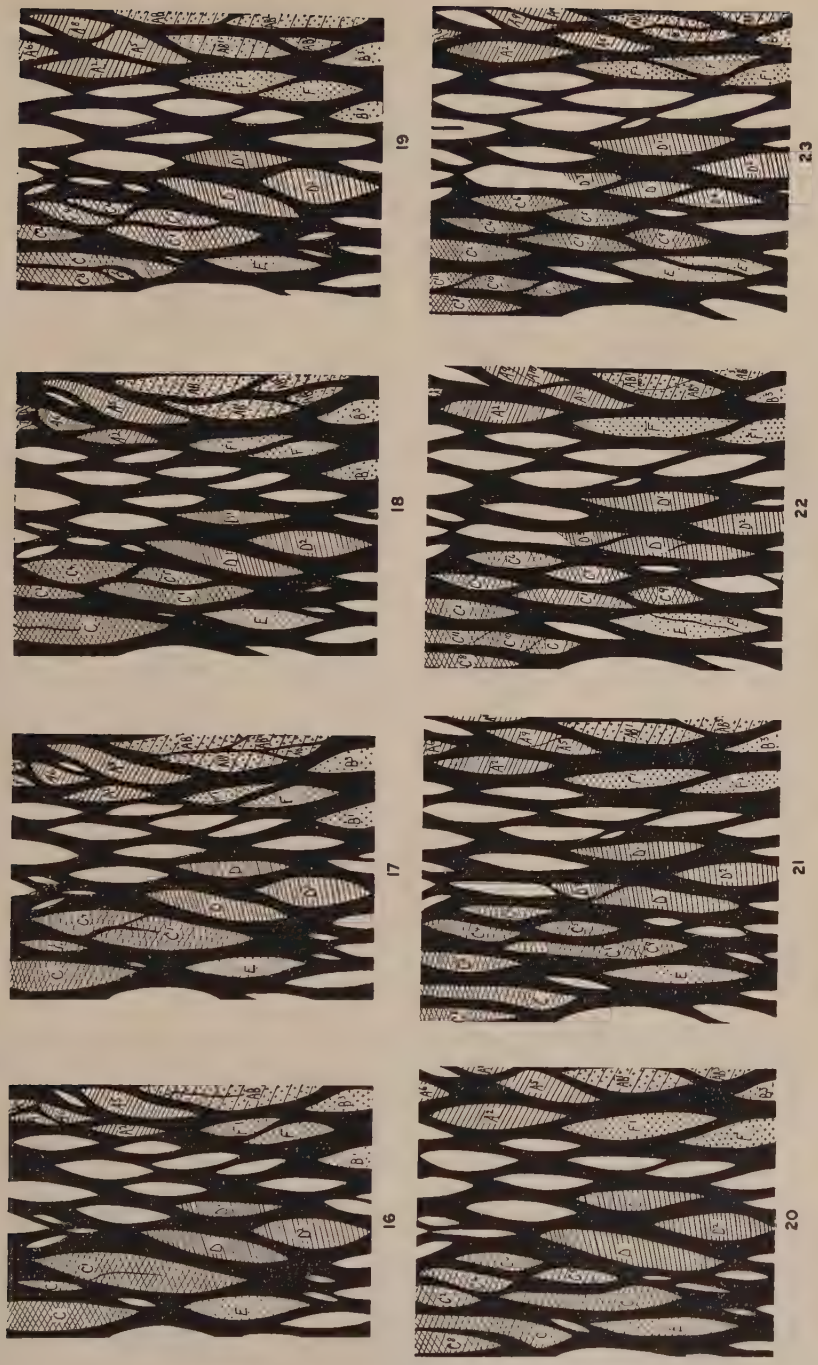
The products of a single ray of *Theobroma mariae* (Mast) K. Schum are shown in Text-fig. 3. Two splits are seen beginning in section 110, which, together with another initiated later, separate off the four rays seen in section 170. Here one of the rays splits again, and the original ray is divided into five smaller rays. Another split in the upper ray produces the final cluster shown in section 362; six rays in all, coming from the single ray shown in section 1. All the rays except one continue to grow, and undoubtedly would, if the sections were continued, be found to split still further. In the small ray, however, the reverse process is to be seen, and the ray, instead of growing and dividing, starts to dwindle, until, as shown in section 362, it becomes a small uniseriate ray. The dwindling of a whole ray to the point of extinction is an uncommon feature of ray growth though single cells are frequently lost by a similar process.

INCREASE IN SIZE OF INDIVIDUAL RAYS.

The two methods by which the rays are spread through the wood are thus seen to be by the formation of new uniseriate rays, and by the splitting up of large ones. Growth in size may also take place in two different ways. Rays



TEXT-FIG. 2. Development of the rays through 3 inches of wood, showing increase in number by splitting. (No. 1 from a section near the pith.) The cross-hatching of



each ray shown in No. 1 is retained throughout the series for that ray and its derivatives. *Cola togoensis* Engl. and Krause. (× 5.)

usually increase the number of their cells by the swelling and division of the ray initials, the peripheral ones being larger and dividing more actively than those in the centre. This type of ray growth adds to the width of the ray, and at the same time to the circumference of the stem, by the production of new cells. Rays may grow in height by the cells at the apex swelling, pushing up between adjacent fusiform initials, and then dividing.

A limit of 3 to 5 cells in width appears to be set to the rays of some genera,

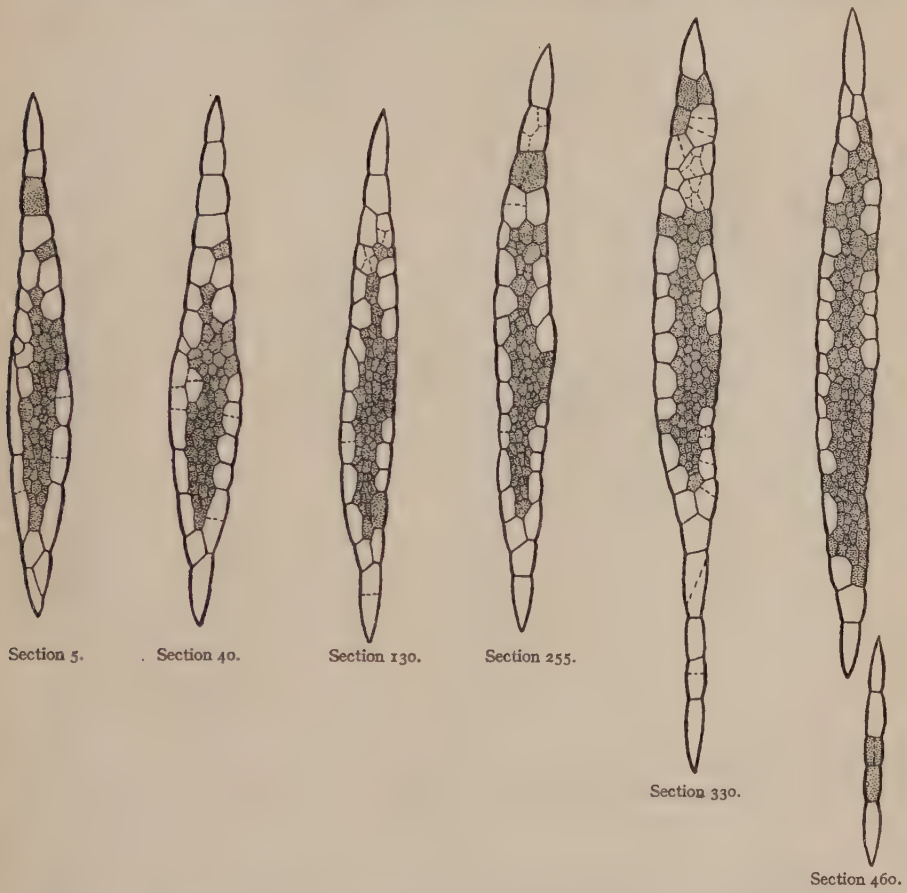
TEXT-FIG. 3. Derivation of a group of six small rays from one large one. Series selected from sections at 30 μ intervals through 10 mm. *Theobroma mariae* (Mast) K. Schum. ($\times$ 35.)

such as *Eriolaena* and *Dombeya*, but in *Theobroma*, *Fremontia*, and many of the sub-family Sterculieae this width is greatly exceeded. In *Fremontia* the rays cease to grow in width beyond 12 to 14 cells; each new ray increases to about that size, and then growth slows down and finally ceases. In many species of *Theobroma*, however, there seems to be no cessation of growth, and the ray tissue is kept at a limited size only by the process of splitting already referred to. *Fremontia* shows the first method of spreading the rays, *Theobroma* the second; in *Fremontia* the limited size is associated with the formation of numerous uniseriate rays, in *Theobroma* the very large rays are associated with the reversion of ray initials to the fusiform condition.

Occasionally growth in height may take place more suddenly by a fusiform initial immediately above or below the growing ray changing into a series of ray initials. This is shown in Text-fig. 4 for *Tarrietia utilis* Sprague. The

newly added initial usually remains attached to the existing ray, and grows with it, but occasionally, as in the wood figured, it may become separated from the larger ray while it is still in the uniseriate condition, in which case it continues to grow as an independent ray.

This method of growth by converting adjacent fusiform initials to ray

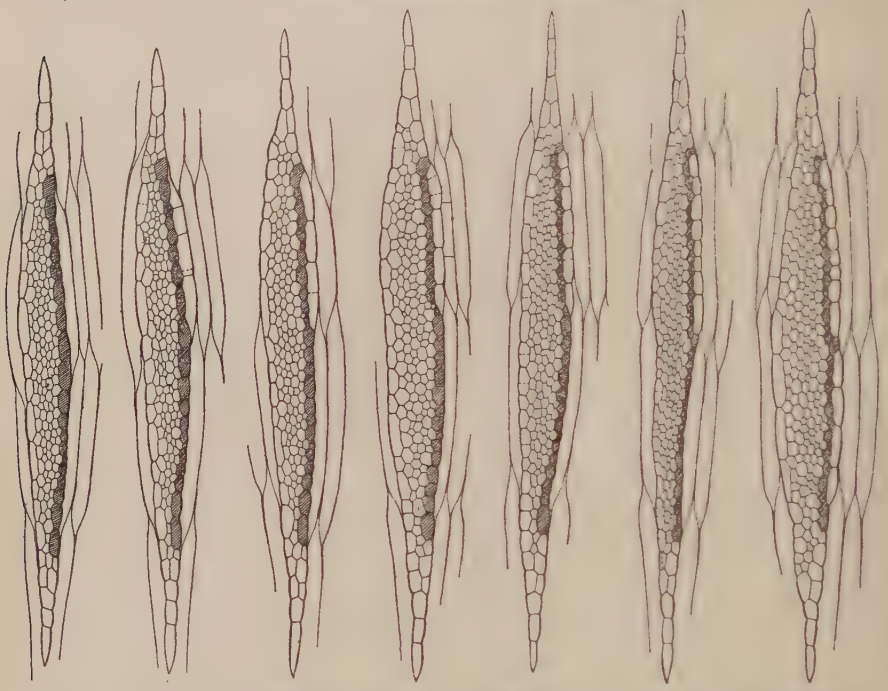


Text-fig. 4. Gradual subdivision of added initials, forming sheath-cells and ultimately procumbent cells. The fusiform initial which is added to the bottom of the ray in section 330 is subsequently separated from it and gives rise to an independent uniseriate ray (section 460). *Tarrietia utilis* Sprague. (×85.)

initials, and their addition to an existing ray, is the second method of growth already referred to. The addition of a whole fusiform initial to increase the height of a ray occurs in many of the woods of this family, but in the subfamily Sterculieae new initials are also added to the sides of the rays. These new initials are at first only subdivided into three or four cells, and are very similar to parenchyma strands, which may indeed easily be mistaken for newly added ray initials. Once they have been added to the ray, however, these

initials persist, and appear in all subsequent sections, whereas a parenchyma strand, which results from extra-cambial subdivision of a daughter cell, is only transitory, and gives place in subsequent sections to the usual radial sequence of fibres, vessels, and parenchyma.

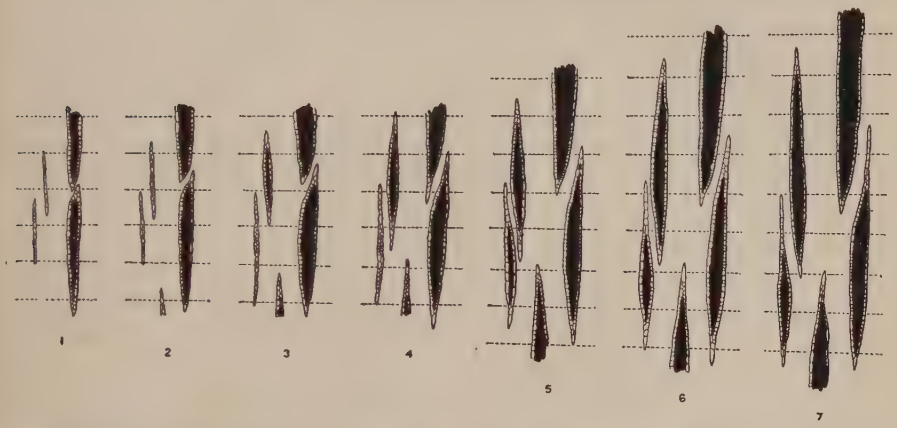
It is this process of adding a layer of cells down the side of the ray which gives rise to the marginal sheath of larger cells by which the rays of this subfamily are completely or partially surrounded. Details of their formation have



Text-fig. 5. Formation of sheath-cells by the addition and subdivision of adjacent fusiform initials. *Pterocymbium javanicum* R. Br. (×45.)

been studied in *Pterocymbium javanicum* R. Br. in which there is a very conspicuous layer completely surrounding the rays. Text-fig. 5 shows a series of camera lucida drawings selected from serial sections 30 μ thick through $\frac{1}{2}$ inch of mature wood. In order to follow the changes in size and position more easily all the peripheral cells on the right of the ray are shaded in the first drawing, and the same cells are shaded in all the subsequent ones. These cells are larger than the central cells of the ray and are bordered by successive fibrous or parenchymatous cells of the ground tissue of the wood, or occasionally by vessels. In section 35 the cell lying immediately to the right of the ray in the upper story is subdivided and looks very like a parenchyma strand. This subdivision has, however, taken place in the initial, and not extra-cambially, and it persists through all subsequent sections. This new cell-layer is now the peripheral layer of the ray, which has increased in width, and it

replaces the former peripheral layer, the cells of which are undergoing further subdivisions, and becoming smaller. The newly added cells are at first very large, but they become smaller through the formation of transverse walls, and ultimately assume much the same proportions as the cell-row which they replaced. Meanwhile similar changes are taking place in other parts of the ray. The shaded peripheral cells in the lower part of the ray have undergone subdivision, and in section 307 a new initial is added to the ray in the lower story, and at the same time another initial is added on the opposite side of the ray. In section 222 the lower half of the ray appears much narrower than it was in



Text-fig. 6. Successive sections at 1½-inch intervals, showing development of two uniseriate rays. The horizontal dotted lines represent the limits of the stories in the other elements. *Pterocymbium javanicum* R. Br. (×10.)

section 144, which may possibly correspond with the change from erect to procumbent cells. It is not possible to check this fact, as it necessitates being able to see both radial and tangential sections of the same cell at the same time, but the slight shrinkage in tangential area which is frequently seen in the initials at this stage of ray growth is probably associated with extra-cambial radial elongation of the ray cells.

Text-fig. 6 shows a more general view of ray growth in the same wood. The sections shown in Text-fig. 5 were taken from between Nos. 3 and 4. The whole range of figures in this fig. represents sections at ½-inch intervals through 3½ inches of wood. Number 1 shows two large rays, one 3 stories high and the other, only partly shown, 13 stories high. These rays are separated from one another by one fibre, and each is surrounded by a conspicuous sheath of larger cells. On their left are two uniseriate rays each of which has arisen through the change of a fusiform initial into a series of ray initials. The growth of these rays can be traced through the whole 3½ inches; at the end of the series they are seen to be 4 and 5½ stories high respectively, and to have acquired a complete layer of sheath-cells. The increase in size has taken place in two ways: by cell division, and by the conversion of fusiform initials to ray

initials and their addition to the existing complex. Growth in height has been gradual, except in No. 3, by swelling and subsequent division of the apical initials which push their way in among the surrounding elements. This accounts for the fact that increase in height is for the most part independent of the stories. The exception to this is between Nos. 2 and 3, where one of the uniseriate rays is seen to have jumped a complete story by the addition of a whole converted fusiform initial.

These sheath-cells, which are so conspicuously developed in *Pterocymbium*, are present in all members of the sub-family Sterculieae, except *Heritiera*. In some genera they are much less regular than in others, and sometimes they form only a partial sheath around the ray; in this case ray growth takes place mainly by division of the existing initials, supplemented by the occasional addition and conversion of fusiform initials.

This method of growth is evidently at the expense of the fusiform initials which form the ground tissue of the stem, and contributes nothing to the increase of the perimeter. In rare cases it may use up all the fusiform initials between two rays, so that they fuse into one. But this is unusual because the fusiform initials usually multiply by radial division more rapidly than they are absorbed by the rays.

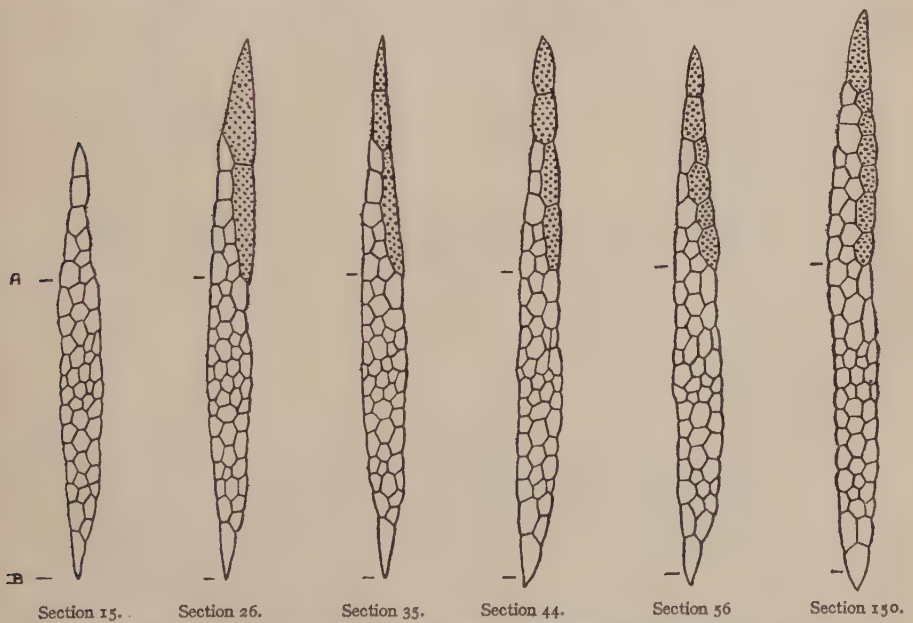
The phenomenon of splitting rays appears to have little systematic importance, and to depend almost directly on ray size. The concentration of growth into a few very large rays has two results: firstly, it produces a very uneven distribution of ray tissue through the stem, large patches of ray tissue and large spaces without any; and, secondly, it produces rays in which the peripheral cells which are in contact with other elements of the wood are few compared with the number of inner cells which are surrounded by one another. Thus the splitting of a ray has two effects: the ray tissue is spread more evenly through the stem, and the surface of the rays is increased in proportion to their bulk. A study has been made in the Sterculiaceae of the ratio of surface to mass, using the perimeter and area of a ray as seen on the tangential section, but at present it is not possible to say more than that it suggests that the splitting process is closely related to a low ratio. In the small-rayed genera, and in the small rays of all genera, this ratio is very high; with slight increase in the size of the rays it falls very rapidly, since the area is approximately doubled when a uniseriate ray becomes biseriate, while the increase in surface is small. In the larger rays the ratio decreases more slowly, and the result is a curve which is steep at first but finally flattens out, as in a typical logarithmic growth curve. For each species there appears to be a 'danger zone' on this curve, and when the ratio reaches this the ray is liable to divide.

In *Sterculia quinqueloba*, although the rays were traced through nearly three thousand sections, no complete splitting was observed. Several times a ray began to split, several ray initials reverted to the fusiform condition, but the split was never completed and the ray either remained in this condition permanently, or, more frequently, the reverse process took place, and the split closed up. From this it would appear that the proportion between surface and

mass imposes a limit to effective ray size, but that the actual process of splitting depends on some internal factor. Similarly in *Sterculia urens* rays began to split, often in considerable numbers; these were followed in sections through 6 inches of the wood, and initials which had changed, reverted to ray initials. Finally, however, some factor must have intervened to upset the balance, for within a few millimetres several rays were found to have completed the split. In both these woods it was very noticeable that the splits almost always started from the same end and side of the different rays, which suggests a physiological impulse passing up or down the tree. It has not been possible yet to procure material in which the top could be distinguished from the bottom of the specimen, so this point remains unsettled.

DISTRIBUTION OF RAY TYPES WITHIN THE FAMILY.

In attempting to review this family from the standpoint of the rays the first difficulty encountered is its great heterogeneity, and the first conclusion at which one arrives is that the development of the rays is not parallel to the systematic classification of the family. The only really homogeneous sub-family is the Sterculieae, and even here *Tarrietia* and *Heritiera* present certain anomalies which suggest that they stand somewhat apart from the rest of the sub-family. The Sterculieae have, however, two features which separate them



TEXT-FIG. 7. Exceptional development of a layer of sheath-cells in a wood from which they are normally absent. *Mansonia altissima* A. Chev. (× 130.)

from the rest of the Sterculiaceae: none of the genera have rays with tile-cells, and in all except *Heritiera* sheath-cells are developed to some extent.

Previous work (2) has shown that this sub-family also stands apart as regards

the distribution of the vertical wood parenchyma, and that the genera can be arranged in a progressive sequence according to the characters of the vessels and the vertical wood parenchyma. This sequence corresponds closely with the relative abundance of sheath-cells, and it appears that abundance of sheath-cells and the method of enlarging the rays at the expense of the fusiform initials is a primitive feature, and that the small-rayed species are on the whole more advanced than the large-rayed ones. It is, therefore, possible that the history of the rays is one of reduction from the unwieldy rays of the Sterculieae to the small rays of *Mansonia*, and that the occasional retention of the power to add a fusiform initial is a reversion to a lost character rather than a stage in the acquisition of a new one. In all the woods of which tangential serial sections were cut it was found that a fusiform initial was occasionally added to the side of a ray, producing locally a series of about four sheath-cells. This was observed in one case even in *Mansonia altissima* A. Chev. Here a ray had grown unusually tall and pushed into the story above, a new initial had been added to it, and the process of division was exactly similar to that already described for *Pterocymbium*.

In the present state of the work all attempts at assigning affinities to the different genera are bound to be somewhat speculative, but the following scheme has been devised to provide a working hypothesis.

Group A. Rays with Sheath-cells. (Sub-family Sterculieae.)

Growth by subdivision of existing initials and by addition of adjacent fusiform initials and their conversion to fusiform initials.

Growth mainly by addition of adjacent fusiform initials. Sheath-cells usually forming a complete layer round the rays. Rays often very large and of unlimited growth.

Pterocymbium.
Sterculia sp.

Growth partly by addition of new initials and partly by subdivision of existing ray initials. Sheath-cells often only partially surrounding the rays. Rays sometimes very large, and of unlimited growth.

Firmiana.
Pterygota.
Scaphium.
Sterculia sp.
Tarrietia sp.

Growth mainly by the subdivision of existing ray initials. Sheath-cells often spasmodic and irregular in occurrence.

Rays large, and of unlimited growth.

Brachychiton.
Cola sp.
Eribroma.
Sterculia sp.

Rays small, usually of limited growth.

Cola sp.
Heritiera.
Sterculia sp.
Tarrietia sp.

Group B. Rays normally without Sheath-cells. (Other sub-families of the Sterculiaceae.)

Growth entirely by subdivision of existing ray initials.

Rays often very large, of unlimited growth.

**Guazuma.*
**Leptonychia.*
**Pterospermum* sp.
**Scaphopetalum.*
Theobroma.

Rays of limited growth, in some genera very small. Largest rays 6–12 cells wide.

Cheirostemon.
Commersonia.
Dombeya sp.
Eriolaena sp.
Fremontia.
**Reevesia.*
**Triplochiton.*

Largest rays 2–4 cells wide.

Dombeya sp.
Eriolaena sp.
Helicteres.
**Kleinhovia.*
Mansonia.
**Melochia.*
**Pterospermum* sp.
Waltheria.

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* Rays with tile-cells; resulting from numerous extra-cambial subdivisions of the ray initials.

SUMMARY.

(1) Ray development of the wood of various genera of the Sterculiaceae has been studied by means of serial tangential sections from the pith outwards.

(2) Increase in the number of rays, to keep pace with the increasing perimeter of the stem, is achieved in two ways: by subdivision of the fusiform initials to form uniseriate rays, and by the formation of several smaller rays from one large one. The latter is effected by the reversion of ray initials to the fusiform condition.

(3) Increase in height and width of individual rays occurs in two ways: by swelling and division of the existing ray initials, and by addition of new ray initials formed from adjacent fusiform initials.

(4) The addition of new initials to the sides of the rays gives rise to the layer of 'sheath-cells' which are characteristic of some genera. These genera are confined to the sub-family Sterculieae, which appears to stand somewhat apart from the rest of the family in this and other respects.

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MOVEMENT OF THE PIT MEMBRANE IN CONIFEROUS WOODS, WITH SPECIAL REFERENCE TO PRESERVATIVE TREATMENT

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INTRODUCTION.

THE impregnation of coniferous timbers with preservatives is attended by certain difficulties chief amongst which are, firstly, the extremely variable absorptions obtained in different consignments of a single species, and, secondly, the non-uniform character of the penetration, due to the dense summerwood portion of the annual ring being far more permeable than the springwood. For most purposes it is the aim of the wood preserver, not so much to achieve complete impregnation, but to obtain a fairly uniform penetration of the preservative to a depth beyond that likely to be exposed by any subsequent checking. The existence of wide variation in the amenability to treatment of apparently similar pieces of timber renders it virtually impossible to specify a method of treating any given consignment of timber which shall be both economical and satisfactory, particularly when incising apparatus is not available; a drastic treatment may result in the whole being adequately treated, but the process is likely to be extremely wasteful owing to the unnecessarily high absorptions of the more permeable specimens. It seemed possible that many of the difficulties encountered in treating timbers might be explained on structural grounds, and to this end a series of investigations were undertaken to examine the relationship between the anatomical characters of wood and its preservative treatment. Some of the results obtained so far from an anatomical study of coniferous timbers are recorded in the present paper.

The main passage for liquid injected into coniferous wood is believed to be through the lumina of the tracheids, the liquid passing from cell to cell through the bordered pits (1, 6). The closing membrane of these pits consists of a centrally thickened portion, or torus, which is generally regarded as impervious to liquids, and an extremely thin peripheral portion in which the presence of minute perforations has been demonstrated (1). In green sapwood the torus usually occupies a more or less central position, leaving the pit membrane freely exposed within the pit cavity, but in air-dry sapwood and in heartwood the springwood pits are closed, or aspirated, owing to the torus having moved towards one side of the pit, thus occluding one of the pit apertures; the pits of the summerwood tracheids and ray-tracheids are said to remain unaspirated (7, 8). The torus has been considered by some to be capable of exerting a valve-like action, thereby controlling the passage of sap in the living tree and

preventing the spread of air-bubbles, although this latter function has been questioned (2). Use has been made (5) of torus position to distinguish between sapwood and heartwood, but this practice is obviously unsound when dealing with dry material. In view of the above hypothesis that liquid penetration is dependent on passage through the bordered pits it is to be anticipated that the position of the torus would affect impregnation considerably, and Griffin (3, 4) has obtained evidence that the proportion of aspirated pits, as observed in samples of creosoted wood, bears a direct relation to the resistance which the wood offers to impregnation with creosote.

The first part of the present paper deals with the effect of drying on torus position; the second part describes a study of the variation encountered in dry wood, for it is in the relatively dry condition that timber is mostly treated in wood-preserving practice, and a knowledge of the variation in torus position appears to be an essential preliminary to the correlation of treatability with microscopic structure. The third part of the paper is devoted to a consideration of torus position in relation to preservative treatment.

1. THE CONDITION IN GREEN WOOD AND THE EFFECT OF DRYING.

The marked difference between the numbers of closed pits in green and dry wood suggests a causal connexion between the condition of the pits and the moisture content of the wood. In order to investigate this relation, the condition of the pits was examined at successive stages in the drying process and some indications were obtained of the possible mechanism by which the drying of wood induces movement of the torus. The material used for this part of the investigation consisted of cross-sectional disks 2 inches in thickness taken at a height of 9 feet from a recently felled tree of Douglas fir (*Pseudotsuga taxifolia* Brit.) and of Scots pine (*Pinus sylvestris* L.). These disks were allowed to dry out in a warm room and small blocks were removed at intervals from the outer sapwood and from the heartwood, daily at first, but less frequently as the drying rate decreased. Tangential sections for microscopic examination were cut from the early springwood and late summerwood of each block, the remainder of which was used for moisture-content determination. Experience with air-dry material had shown that comparable representative sections of springwood may be obtained from anywhere within the first half of the springwood zone, but that for summerwood the sections must be taken within a short distance of the outer boundary of the annual ring (see Figs. 2 and 3). The position of the torus, whether in contact with the pit border or occupying a more or less central position in the pit cavity, was recorded for one hundred pits; tori obviously displaced by the sectioning process, or whose positions were not clearly visible, were disregarded. Staining with an aqueous solution of ruthenium red (1 : 5,000) was found to facilitate observation of the torus.

Results and Discussion.

The proportion of unaspirated pits was plotted against moisture content, but the graphs obtained were found to be rather irregular in form, particularly

those for springwood. This appeared to be due mainly to the relatively small number of observations recorded for each sample; very few tracheids need be examined to observe 100 pits, and consequently such counts are not fully representative. Certain salient features were shown, nevertheless, by the figures obtained:

(1) In green wood aspirated pits occur even when a considerable amount of free water is still present.

(2) As the wood dries the number of aspirated pits increases gradually until fibre-saturation point is approached; at this stage nearly all springwood pits have become aspirated.

(3) A certain proportion of the summerwood pits remain unaspirated in dry wood.

The heartwood was found to be below fibre-saturation point at the start, and so the effect of drying was studied only in the sapwood. It may be noted that resoaking dried wood does not serve to reopen the pits.

A further series of observations was made on a disk of Corsican pine (*Pinus*

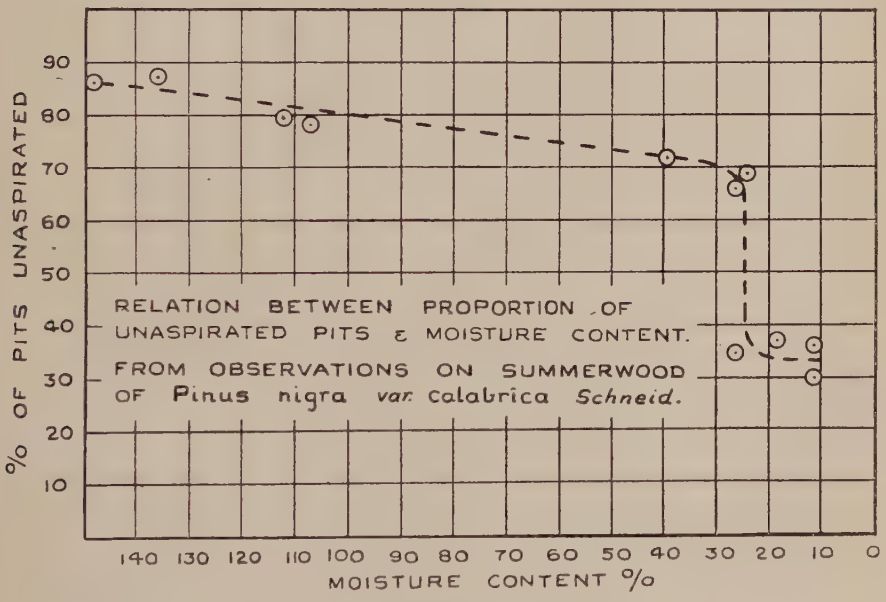

FIG. 1.

nigra var. *calabrica* Schneid.). This time 300 pits were observed at each moisture content, the same annual rings being examined throughout; late summerwood pits only were examined, as these are more readily observed and their relative sparseness ensured examination of a large number of tracheids. The results (see Fig. 1) confirm the presence of aspirated pits in green wood, and a well-marked and sudden increase in the number of closed pits is shown to occur near the fibre-saturation point.

Practically nothing is known regarding the cause of torus movement; it

may be that closure of the pit is brought about by evaporation of the last drop of water in the pit cavity, the torus being gradually drawn towards one of the pit apertures. This hypothesis would explain the closing of the majority of the aspirated pits, but another explanation is required to account for the closure which occurs during the early stages of drying. Calculations, based on specific gravity and moisture-content determinations, showed that, in the first blocks of Corsican pine examined, air occupied about 20 per cent. of the volume of the cell cavities. It was observed that in wood in this condition the water columns generally stand at different levels in adjacent tracheids, possibly on account of slight differences in calibre affecting capillarity, and when movement of the columns takes place this is rarely simultaneous and often differs in direction in neighbouring elements. Now this differential movement would result in conditions under which torus movement might be anticipated, for as one tracheid becomes filled with air an annular meniscus will be formed in each pit between the pit aperture and the torus; it may be reasoned that the surface tension thus brought into play will tend to pull the torus towards the aperture, since no such force is acting on the opposite side of the pit. It appears significant that considerably more aspiration occurs in springwood than in summerwood during the early stages of drying; this would be expected since the closure of the pit will depend on the surface tension being sufficient to overcome the resistance offered by the rigidity of the pit membrane and the inertia of the torus. In springwood the greater periphery of the pit aperture will result in a higher surface tension being set up, while the resistance offered by the more delicate torus and pit membrane will not be correspondingly greater. Another possible factor conducive to earlier aspiration in springwood is the more rapid drying of springwood as compared with summerwood. Where the pit is more stoutly constructed, as in the case of the summerwood pits, the rigidity of the membrane and torus may be sufficient to prevent aspiration. It is frequently observed that some pits on the same tracheid wall are aspirated while others are not, and, less frequently, that some are closed towards one pit aperture and others towards the other. It has not been possible to detect any structural difference between such pits, and it seems probable, therefore, that much of the difference in behaviour of adjacent pits is due to temporary differences set up during the dynamic process of drying.

Various methods of drying were tried, but the results in terms of pit aspiration were similar. These methods included oven-drying, air-drying, boiling followed by oven-drying, and drying over calcium chloride, i.e. rapid drying at both high and low temperatures, and relatively slow drying.

It was found by Griffin (3) that when green wood was soaked in alcohol and the alcohol then allowed to dry out of the wood, aspiration of the pits generally did not occur. This fixative action was examined during the present investigation, small blocks adjacent to those used for the experiments already described being submerged in 97 per cent. alcohol immediately after their removal from the disk and allowed to remain immersed for at least 48 hours. A portion of each block was then sectioned and the remainder oven-dried and again sectioned.

This treatment was found to have prevented further aspiration of the pits taking place during drying in both the Douglas fir and Scots pine material, the alcohol having apparently fixed the pit membranes in the positions they occupied in the green wood; in Corsican pine, however, the treatment was not effective in preventing pit closure.

The fixative effect of the alcohol may be accounted for on the basis of the above hypothesis, i.e. that aspiration of the pits is brought about by surface-tension forces. Water, at room temperatures, has a surface tension approximately three and one-third times that of alcohol: it might be expected, therefore, that the relatively small force tending to pull the torus to one side when alcohol dries out of the pit would be insufficient to bring about aspiration. The ineffectiveness of this method for preventing pit closure in the material of Corsican pine is attributed to the presence of considerable quantities of resin in the wood. This dissolves in alcohol and increases the surface tension; the liquid in which blocks had been submerged was found to have a surface tension 19 per cent. greater than the original alcohol; within the block itself the concentration of resin must have been considerably greater, with a proportionate increase in the surface tension.

2. THE CONDITION IN DRY WOOD.

It has been shown that nearly all the springwood pits are aspirated in dry wood whilst a certain proportion of the summerwood pits remain unaspirated; this appears to be typical of all species investigated. It was decided, therefore, in studying the degree of variation in the proportions of unaspirated pits in air-dry wood of the commoner home-grown conifers to deal mainly with summerwood.

Observations made at various times on air-dry wood taken from corresponding positions in different annual rings, and at various moisture contents below fibre-saturation point indicated that the torus is in a stable condition in dry wood; consequently the effect of differences in moisture content below fibre-saturation point can be ruled out. The study of variation was, therefore, confined to that due to the position of the pits, firstly, relative to the boundaries of the annual ring, and secondly, relative to the distance of the annual ring from the pith.

Results and Discussion.

Variation within the annual ring. The results obtained from an examination of a complete annual ring which had been cut into a series of tangential sections each 8 μ in thickness showed that the proportion of unaspirated pits increases in passing from springwood to summerwood, and that the change, whether gradual or sudden, corresponds with the change in density of the wood as apparent to the naked eye. Figs. 2 and 3 are examples of torus behaviour in two contrasted types of annual ring. The transition from springwood to summerwood is accompanied by an increase in thickness of the tracheid walls, in fact this is the main distinguishing feature between the two portions of the

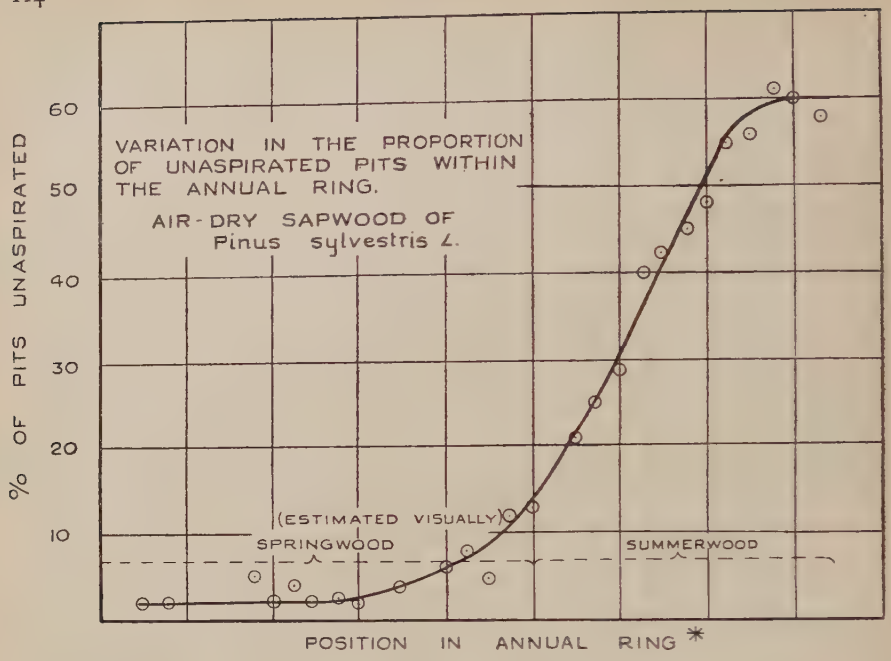

FIG. 2.

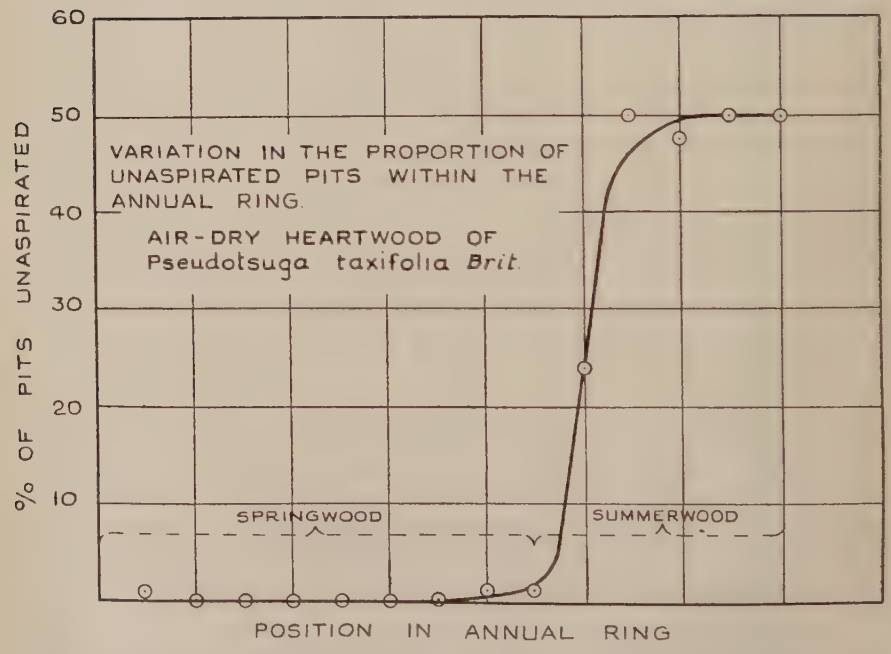

FIG. 3.

* In Figs. 2–5 each division of the horizontal scale corresponds with a distance of approximately 320 μ measured radially across the annual ring.

ring. This parallel with wall thickness suggested that the resistance of the bordered pits to closure is correlated with the degree of wall thickening more closely than with changes in the dimensions of the pits themselves. In support of this hypothesis it may be mentioned that while the proportion of unaspirated pits increased in accordance with the increase in wall thickness, the diameter of the pits, although diminishing in the summerwood, did not change *pari passu* with the degree of wall thickening. Again, the home-grown Douglas fir showed a much higher percentage of summerwood pits aspirated than did the Canadian material; this corresponded with the much thicker walls of the latter, whilst there was no significant difference between them with respect to pit size. The average figures were:

Home-grown Douglas fir:	
Percentage of pits unaspirated	21
Average thickness of radial walls	6 μ
Canadian Douglas fir:	
Percentage of pits unaspirated	53
Average thickness of radial walls	11 μ

Whether the greater thickening of the secondary wall (which forms the pit border) in itself offers resistance to those forces tending to close the pit, or whether such thickening is merely indicative of a generally stouter and more rigid construction of the pit membrane and torus, it was not found practicable to determine, but it is noticeable that the torus, which in the springwood is in the form of a thin flat disk and is fairly flexible, as indicated by its dimpled appearance when applied to the pit aperture, is inflexible and considerably thicker in the summerwood.

Variation with distance from the pith. In order to examine the relation between the proportion of aspirated pits and the distance from the pith, observations were made on the late summerwood of certain annual rings at intervals along a radius of a cross-sectional disk taken from at least one tree of each of the following five species: *Larix decidua* Mill., *Picea Abies* Karst., *Pinus nigra* var. *calabrica* Schneid., *Pinus sylvestris* L., and *Pseudotsuga taxifolia* Brit. No striking differences were apparent in the proportions of unaspirated pits at various distances along the radii, although near the pith the proportions were high in relation to the wall thickness; this is probably due to the small size of these pits compared with those in more adult wood. As would be expected from the hypothesis that pit closure is due to drying, no significant difference was shown between dry heartwood and sapwood.

Differences between species. The figures for these samples and for various other samples of the species, although showing considerable ranges of variation, are interesting since the averages were considerably higher for some species than others. In view of the suspected relation between torus position and wall thickness, measurements were made to determine whether the differences between species could be accounted for on the basis of differences in wall thickness. These measurements, made on adult wood of each species, are shown in Table I.

TABLE I

Material.	*Percentage of pits unaspirated in dry wood (summerwood).*	*Average thickness of tracheid wall (summerwood).* (μ)
Larix decidua . .	33	7·0
Picea excelsa . .	35	8·5
Pinus nigra var. *calabrica*	40	6·0
Pinus sylvestris . .	60	8·0
Pseudotsuga taxifolia .	20	6·0

It is concluded from these figures that for a given wall thickness, the pit membranes are more rigid in some species than in others. The two *Pinus* species appear to possess pit membranes comparatively rigid in relation to the thickness of their cell walls. A general comparison between the proportions of aspirated pits in the different species is impracticable in view of the existing variation and the small amount of data at present available.

3. THE RELATION OF TORUS POSITION TO PRESERVATIVE TREATMENT.

If we accept the conclusion of Griffin (3), that degree of penetration of creosote is proportional to the percentage of unaspirated pits present, and assume that this percentage is itself correlated with the thickness of the tracheid walls, it follows that in denser samples of a species deeper penetration is to be expected, presuming that the impregnation process does not affect

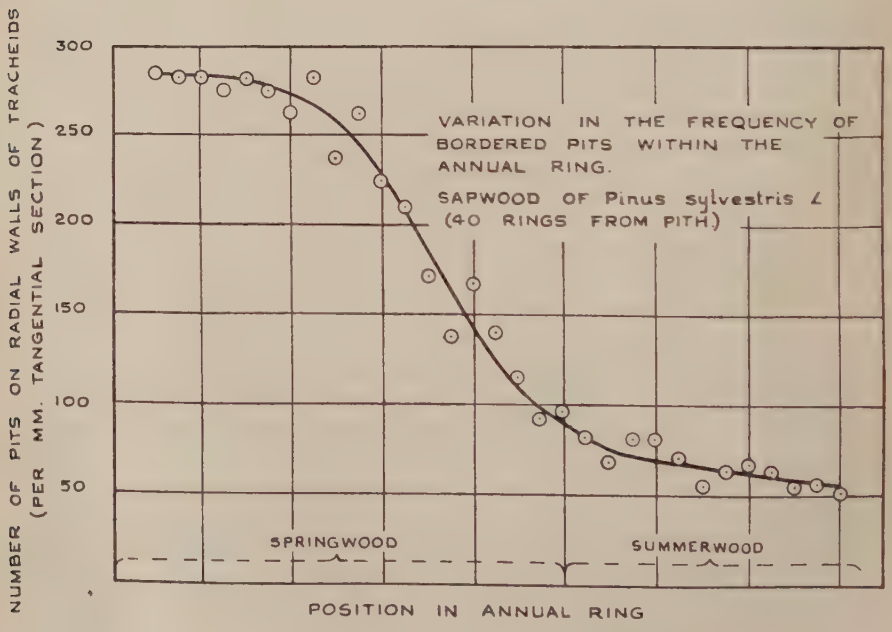

FIG. 4.

the position of the torus. In attempting to correlate torus position with the amenability of the wood to treatment, however, the actual number rather than the proportion of unaspirated pits in each tracheid must be considered, for, on the assumption that fluid preservatives pass from one cell to another through the bordered pits (1), it is obvious that at least two pits in each tracheid must remain open, one to act as an inlet and the other as an outlet, in order to allow of a continuous passage through the wood. The observations recorded in Table II are interesting from this viewpoint. It will be seen that in the air-dry condition the springwood of some species has less than the requisite minimum number of unaspirated pits per tracheid, while the summerwood has sufficient for complete penetration to occur, provided their distribution is fairly uniform. Observations show that this is rarely the case, so that it is doubtful whether a continuous passage via the pits exists even in the summerwood of certain species. The theoretical limits of the permeable and impermeable portions of the annual ring is shown, for a ring of Scots pine, by the horizontal dotted line (*ab*) in Fig. 5 which has been derived from Figs. 1 and 4.

TABLE II

Species	*Average number of pits per tracheid (by indirect method).*[1]		*Average Percentage of pits unaspirated.*		*Average number of unaspirated pits per tracheid in air-dry wood.*	
	Spring-wood.	*Summer-wood.*	*Spring-wood.*	*Summer-wood.*	*Spring-wood.*	*Summer-wood.*
Larix decidua . . .	90	8	1	29	0·9	2·3
Picea excelsa . . .	90	25	7	31	6·3	7·8
Pinus nigra var. *calabrica* .	49	12	1	40	0·5	4·8
Pinus sylvestris . . .	70	17	2	66	1·4	11·0
Pseudotsuga taxifolia . .	92	8	1	25	0·9	2·0

The results of this investigation obtained so far lead to a better understanding of the mechanism of impregnation and help to explain some of the

[1] *An indirect method of determining the number of pits per tracheid.* The direct method, i.e. examination of macerated material, was found to be exceedingly tedious, and the following indirect method was therefore devised whereby the determination is reduced to a series of relatively simple observations. The number of pits visible in about 3 sq. mm. of a tangential section was noted, and also the average tangential width (*w*) of the tracheids. Average tracheid length (*l*) was determined on macerated material. The number of pits (each with two borders) counted in tangential section is only one half the number observable on the tracheids separated by maceration, as in this case each pit visible consists of a single border only; the number of pits per tracheid (*n*), therefore, is equal to twice the number of pits (2*p*) discernible in unit area of tangential section divided by the number of complete tracheids calculated to fill this area, or

$$n = 2\,plw.$$

Figures obtained by this method were found to agree closely with direct observations. When using the method, it is necessary to examine sections properly in the plane of pitting; if very thin sections are used, a considerable area of the section may be taken from near the tangential walls, and consequently will be devoid of pits. Again, the results given by this method will be too low in cases where biseriate pitting is of general occurrence.

difficulties associated with the treatment of softwoods. It is evident that the potential conducting system through the bordered pits as observed in untreated dry wood is, for the most part, inadequate; even in the summerwood of some species a continuous passage is dependent on a uniform distribution of the unaspirated pits, and it may well be that variation in the distribution of these pits is related to the variable absorptions of preservative obtained in practice. The figures given above offer a rational explanation for the greater

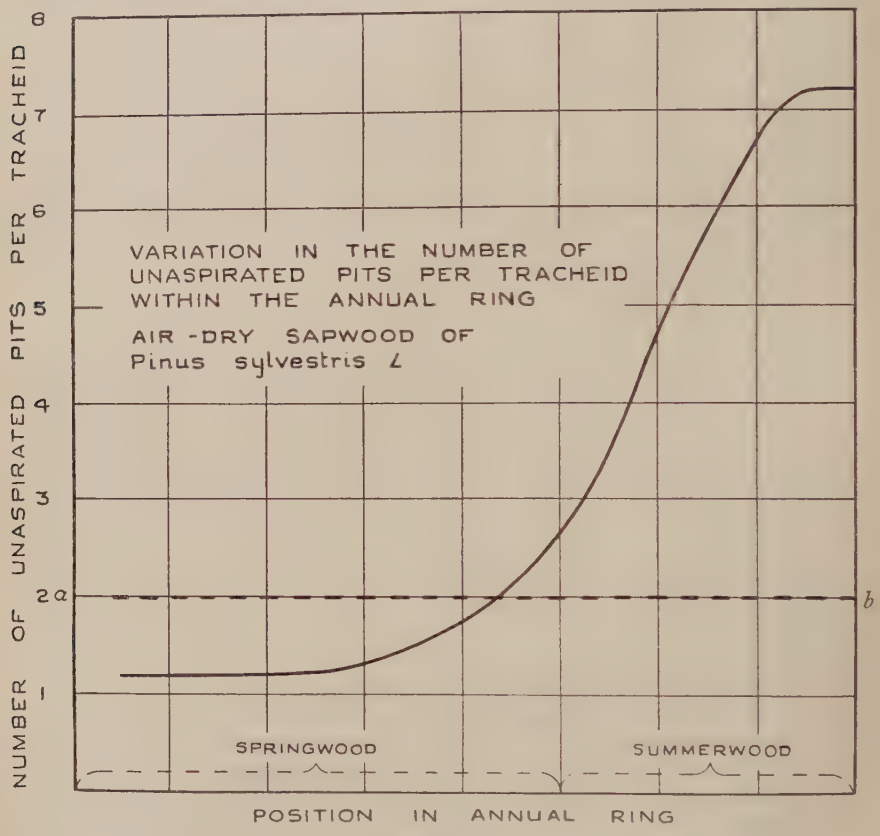

Fig. 5.

permeability of summerwood generally observed. As regards the practical application of these results, it would appear that advantage might be taken of the easy passage afforded by a high proportion of unaspirated pits by treating timbers in the green condition, preferably employing a method whereby the preservative is drawn through the timber rather than applying pressure on all sides. The hypothesis that the fixative effect of alcohol is due to the low surface-tension of this liquid is suggestive, although, at present, it hardly seems economic to treat timber in the green condition with a liquid of low surface-tension in order to facilitate subsequent impregnation of the dry timber with preservative. Such a method, however, might conceivably be useful under

certain circumstances, such as in dyeing processes, where relatively small quantities of wood are used but thorough impregnation is essential.

Several fundamental problems connected with the preservative treatment of softwoods still remain unsolved. Precisely how the change from sapwood to heartwood affects the treatability of softwood timbers has not been satisfactorily explained; and the important question how the application of pressure treatment reacts on the delicately balanced mechanism of the pit membrane requires examination. It is recognized also that the physical and chemical constitution of preservative fluids is a highly important factor in determining the manner of their penetration. It is hoped to throw some light on these and allied problems in the course of future investigations.

ACKNOWLEDGEMENTS.

I am indebted to Mr. W. A. Robertson, F.R.G.S., Director of Forest Products Research, for permission to publish this article; and to Mr. B. J. Rendle, Officer in charge of the Wood Structure Section of this Laboratory, whose previous work on torus movement during the drying of larch timber led him to suggest to the writer the investigation which is reported in the first part of this paper.

SUMMARY.

1. The relation between the proportion of aspirated pits and the moisture content of the wood of various conifers is described.

2. Some aspirated pits occur in green wood containing much free water; the number slowly increases as the moisture content falls until fibre-saturation point is approached, when a rapid increase occurs. At this stage nearly all springwood pits have become aspirated, but a certain proportion of the summerwood pits remain unaspirated even in dry wood.

3. The mechanism of torus movement is discussed and a hypothesis put forward which may also explain the action of alcohol in preventing aspiration of the pit during drying.

4. Variation in the proportion of pits aspirated in dry wood appears to be correlated with differences in the thickness of the radial walls of the tracheids. A new method is described (see footnote, p. 117) for estimating the number of pits per tracheid, and this has been applied in determining the actual numbers of unaspirated pits in tracheids in different portions of the annual ring.

5. The results are considered in relation to the penetration of liquids and the difficulties encountered in treating coniferous timber with preservatives.

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THE FORM OF THE STEM IN CONIFEROUS TREES[1]

(*Continued*)

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IN the earlier sections of this paper we have discussed the stem form of a number of conifers and we have seen that, once allowance has been made for the disturbing effects of root swelling, all these conifers have substantially the same stem form under bark. This brings our work into line with recent work in other countries, and at the same time it opens the way for further developments in our technique of mensuration. But before the newly established facts can be brought into service the way must be cleared still further, and we must, for example, learn something about the distribution of the different form-classes in our stands and, if possible, the factors that govern it. Root swelling and bark thickness also call for investigation.

Form-class Distribution within the Stand. Material for this study was obtained from three plots which were clear-felled but which, before felling, had been treated as ordinary sample plots, the trees being classified and the usual measurements made. After felling, each tree was measured as it lay on the ground. The species were Sitka spruce, Norway spruce, and European larch.

The usual form-classes 60·0, 62·5, 65·0, &c., were used for this part of the work instead of the wider classes employed in the preceding sections, and the trees were reclassified according to their stem curves into the new form-classes. The range of classes was found to be widest and most irregular in the plot of Sitka spruce (from 52·5 to 85·0) and narrowest in the European larch (from 60·0 to 75·0). The data were then examined to discover whether there was any difference between the dominant, co-dominant, and sub-dominant trees in respect of form-class distribution. The results are given in the following tables:

TABLE XXX.

Norway Spruce. Blairadam.

Stem-class.	*Form-class. Numbers of stems.*								
	62·5	*65·0*	*67·5*	*70·0*	*72·5*	*75·0*	*77·5*	*80·0*	*82·5*
1 (Dom.) . . .	1	5	10	29	24	28	19	10	2
2 (Co-dom.) . . .	1	1	5	12	20	11	13	9	3
3 (Sub-dom.) . .	1	2	2	6	8	2	6	2	2

[1] Continued from *Forestry*, vii, No. 1, pp. 32–42.

TABLE XXXI. *Sitka Spruce. Durris.*

Stem-class.	*Form-class. Numbers of stems.*													
	50·0	52·5	55·0	57·5	60·0	62·5	65·0	67·5	70·0	72·5	75·0	77·5	80·0	85·0
1 (Dom.) . .	..	1	1	..	1	1	8	10	12	26	17	3	2	1
2 (Co-dom.) . .	1	..	..	1	..	2	7	3	10	10	12	2	..	..
3 (Sub-dom.) . .	..	..	..	1	..	..	2	1	4	..	..	..	..	..

TABLE XXXII. *European Larch. Tintern.*

Stem-class.	*Form-class. Numbers of stems.*						
	60·0	62·5	65·0	67·5	70·0	72·5	75·0
1 (Dom.) . .	1	2	5	7	24	17	9
2 (Co-dom.) . .	..	..	1	3	10	12	2
3 (Sub-dom.) . .	..	..	1	1	1	..	3

The mean form-classes of the dominant, co-dominant, and sub-dominant trees are as follows:

Stem-class.	*Norway spruce.*	*Sitka spruce.*	*European larch.*
1	73·1	71·1	70·3
2	74·1	70·2	71·1
3	73·1	66·9	71·3
Mean of crop	73·4	70·6	70·6

These tables show that there is little difference between the various stem-classes—dominants, co-dominants, and sub-dominants—as regards the distribution of form-classes. In the European larch the dominants have the widest range of form, but their average form-class is lower than that of either of classes 2 and 3, and this appears to be in agreement with Mattsson's (1) conclusions with regard to this species in Sweden. The range of form-classes in the Norway spruce is identical in each of the three classes, while in the Sitka spruce the range in classes 1 and 2 is similar; for class 3 the data are insufficient to give a fair picture.

Mean Form-class in relation to Mean Girth and Mean Height. The mean form-class of the stand in the preceding paragraph is the average of the form-classes of the individual trees in the plot. It is the mean of a wide range of classes.

The mean tree of a plot is generally selected on the basis of girth or diameter, and it is of interest to determine the range of form-class that occurs within a stand in that group of trees which has the mean girth. If it were found that trees of the mean girth were also trees of the mean form, it would simplify enormously our problem, but unfortunately the figures show that in the mean

girth classes there is a range of form-class almost as great as in the complete stand. This is borne out by the following figures.

Mean Form-class.

Form-class.	*Whole crop.*	*Standard Deviation (form-class units).*	*Mean Girth Trees.*	*Standard Deviation (form-class units).*
Norway spruce . .	73·4	±4·46	73·5	±3·76
Sitka spruce . .	70·6	±5.21	73·6	±7.05
European larch . .	70·6	±3·13	70·7	±2·22

In the stands of Norway spruce and European larch, the average form-class of the trees of mean girth corresponded very closely to the average form-class of the whole crop, but in the plot of Sitka spruce there was a considerable difference between the two averages. In this instance, the distribution of girths about the mean was slightly abnormal, whereas in the plots of larch and Norway spruce the distribution corresponded to that of the normal type, and it is possible that a connexion may exist between these facts.

After the trees of mean girth had been examined in each of the three stands, attention was turned to the trees of mean height. The average form-class of the trees of mean height was calculated in each case with the following result:

Species.	*Mean Form-class of Trees of Mean Height.*	*Standard Deviation (form-class units).*
Norway spruce . .	73·5	±4·09
Sitka spruce . .	70·4	±6·13
European larch . .	71·2	±2·50

These averages correspond fairly closely to the averages given for the whole crop, but there is the same wide range of form-class as in the trees of mean girth.

Attempts were also made to correlate form-class with total height, with crown-length percentage, and with breast-height girth, and for this purpose data from the permanent sample plots were used to supplement the data from the three felled plots. No relation could be established between the form-class and either of the two characters first mentioned, and variations in form within a stand appear to be unconnected with variations in total height and in crown length. With girth, on the other hand, there was in many cases a well-marked relationship, and in such instances the form-class was found to diminish as the breast-height girth increased. In other words, the larger the tree, the poorer the form. This did not, however, hold for all plots, and a closer examination of the data showed that this relationship was most strongly marked in young stands which were still growing rapidly.

The data altogether proved insufficient for a detailed investigation of this important subject and much more work remains to be carried out before the variations of form within a stand can be explained. Further investigations in felled plots are urgently required, because it is only in such plots, where every

tree can be measured on the ground, that a satisfactory examination of the material can be made.

Form Variations within Species. The data which have been collected refer not only to a large number of species but also to a wide range of conditions, and it was hoped that a study of the material would enable us to draw some conclusions as to the variations in stem form within a species and to correlate such variations with variations in some of the other factors which have an influence on growth. Unfortunately this hope has not been realized.

The data which were used in this part of the investigation consisted of measurements taken on sample trees in a large number of permanent plots in which eight to twelve sample trees were measured at each determination of the volume. It was felt that since these sample trees were specially selected as being representative of the plots they could be used with some safety, in spite of their small numbers, to give some indication of the form-class of the stands which they represented. It was found, as a result of tests carried out in the felled plots, that a fair approximation to the mean form-class could be obtained graphically by plotting the form-class of each tree against its girth at breast height, drawing a smooth curve through the points to obtain the relationship, and then taking as the mean form-class the value on the curve corresponding to the mean girth of the stand. The mean form-class determined in this way was calculated for a large number of plots, and an attempt was made to establish in each species some connexion between the mean form-class and various other characteristics of the crop. No satisfactory relationship could, however, be established with any of the other factors, which included age, mean height, mean girth, number of stems, and crown length; the variations in form appeared to be independent of these other variables.

Plots in which the form-class was higher than the mean were then classified separately, and particular attention was paid to the factors of locality in each case, but no result was obtained from this examination. Plots with abnormally low form-class were dealt with in the same way, but again no conclusion could be drawn.

The variation in form over a species appears to be the result of the interaction of a complex series of factors and, with the material at our disposal, does not lend itself to explanation. In the forest, therefore, it will be necessary to determine separately the form-class of each individual stand.

Mean Form-class of Different Species. The mean form-class was calculated for each of the more important species, and these average figures are given in the following table together with the range of form-classes met with in each species.

Norway spruce has thus the highest average form-class, while the poorest form is shown by Douglas fir and the two species of larch. Sitka spruce has a lower form-class than Norway spruce, and in the same way Japanese larch is inferior to the European species. These differences may be due to the fact that in Sitka spruce the bulk of the data, and in Japanese larch all the data, have been obtained from young, rapidly growing, immature stands. The low

form-class of Douglas fir can hardly be accounted for in the same way because quite a fair proportion of the data was obtained from a middle-aged stand with

TABLE XXXIII

Species.	*Mean Form-class.*	*Range of Form-classes.*
Norway spruce . .	73·0	57·5–87·5
Scots pine . . .	71·7	60·0–85·0
Corsican pine . .	71·0	55·0–85·0
Sitka spruce . .	70·6	55·0–85·0
European larch . .	69·4	55·0–80·0
Douglas fir . .	66·6	47·5–85·0
Japanese larch . .	66·3	57·5–77·5

trees of good size, and these large trees had a lower form-class than the younger trees which were measured elsewhere. Scots pine and Corsican pine resemble each other closely in form, and both species of pine have an appreciably higher form than the European larch.

The range of form-class in each case is considerable. It is greatest in the Douglas fir and smallest in the larches and Scots pine.

Root Swelling. The importance of root swelling in a study of this kind has already been emphasized, and it has been shown that root swelling extending as far up the stem as breast height has the effect of obscuring the true form-class of the tree. It is therefore necessary to pay considerable attention to this disturbing factor and to make an endeavour to understand its vagaries.

It was found that although the great majority of the trees were affected by root swelling at breast height, a considerable number showed no sign of any distension at this point, and the first step was to separate the trees with no root swelling from those in which root swelling was apparent. When this had been done for each species it became clear that most of the trees without root swelling were small and that it was only on rare occasions that a large tree was found with its breast-height girth undisturbed. This suggested a second classification, namely, by height, and all the trees in each species were thereupon grouped into 10-foot height classes and the amounts of root swelling re-examined in these new classes. The results were interesting because it was seen that, in trees of up to 25 feet in height, root swelling did not extend so far as breast height, while in trees between 25 and 30 feet high it occurred only in a few trees and in each case was very slight. In trees of over 30 feet in height, root swelling was found to extend as far as breast height on almost every tree. In practice, therefore, it would seem to be safe to ignore root swelling on trees below 30 feet in height.

In trees of over 30 feet in height, the amount of the root swelling was found to increase with the girth, and by plotting the amount of the root swelling at breast height against the over-bark girth at the same point it became possible to draw a smooth curve to show the relationship within each species between breast-height girth and the amount of root swelling at that point. Table

XXXIV shows the amounts by which the *under-bark* girths at breast height have been swollen above the normal as a result of root swelling, and these figures are given for the more important species.

Table XXXIV

Breast-height girth over bark. inches.	*Amount of root swelling in inches on under-bark girth at breast height.*						
	Norway spruce.	*Sitka spruce.*	*European larch.*	*Japanese larch.*	*Scots pine.*	*Corsican pine.*	*Douglas fir.*
12	0·15	0·10	0·25	0·22	0·20	0·07	..
16	0·42	0·32	0·62	0·50	0·30	0·22	0·22
20	0·76	0·58	0·91	0·74	0·45	0·31	0·43
24	1·15	0·85	1·15	0·87	0·58	0·40	0·65
28	1·62	1·17	1·35	1·00	0·75	0·50	0·89
32	2·18	1·50	1·55	1·10	1·05	0·60	1·16
36	2·79	1·92	1·74	..	1·45	0·70	1·45
40	3·52	2·37	1·87	..	1·85	0·80	1·78
44	..	2·87	2·00	..	2·25	0·95	2·16
48	..	3·43	2·07	..	2·67	1·12	2·56
52	..	4·05	..	..	..	..	2·98
56	..	4·70	..	..	..	..	3·39
60	..	5·40	..	..	..	..	3·85
64	..	6·13	..	..	..	..	4·30
68	..	7·00	..	..	..	..	4·75
72	..	..	..	..	..	..	5·20
76	..	..	..	..	..	..	5·68
80	..	..	..	..	..	..	6·20

This table is of interest as showing the extent of the root swelling in the different species.

In trees with girths below 20 inches the effect of the root swelling is not very strongly pronounced, but in larger trees it becomes more important, and with increasing girth the amount of root swelling becomes progressively greater. The species least affected by root swelling at breast height are Corsican pine and Japanese larch—European larch, Douglas fir, and Scots pine are more markedly affected, but it is in the species of spruce that root swelling has its greatest effect.

Bark Thickness. In this work we have dealt exclusively with the form of the stem under bark, but in practice we should be concerned mainly with over-bark measurements on either felled or standing trees. It follows, therefore, that we must acquire some knowledge of the variations in bark thickness at different points of the stem before we can use the information which we have obtained about the form of the stem under-bark. Fortunately a large amount of data was available from the measurements of felled trees, and this was examined in detail for each of the species. The results are given in Tables XXXV–XLII. These tables show the bark percentages at breast height and at the different percentages of the length of the stem between breast height and the tip of the tree (10, 20, 30, 40, &c., per cent.), and for the more

important species, these bark percentages are given separately for different sizes of stem. The bark percentage in each case was calculated by the following formula:

$$\text{Bark percentage} = \frac{\text{Girth over bark} - \text{Girth under bark}}{\text{Girth over bark}} \times 100.$$

The tables have been prepared by a graphical method which smoothed out any irregularities. These irregularities, however, were of no great importance, for the points in each series fell into line very readily. Detailed tables are given for Scots pine, Norway spruce, Sitka spruce, European larch, Japanese larch, and Douglas fir, while tables of general averages are given for Corsican pine and the minor species in which the data did not allow of subdivision into girth classes.

The detailed tables are of some interest as showing the variation in bark percentage at different points on the stem. In each species the same feature is exhibited: the percentages in the middle part of the stem are fairly uniform but are smaller than that at breast height or those near the tip of the tree. The rapid increase in bark percentage in the last two sections is characteristic of all the conifers which have been investigated; it is, however, more pronounced in the smaller trees.

In most of the species the bark percentage falls as the girth increases, and this applies generally to trees of all species. In Scots pine and Douglas fir there is little difference between the smallest trees and those of the largest size, and the breast-height percentages in Scots pine remain almost unvaried over the whole range of girth. The tables also show that European larch has a thicker bark than the Japanese species, while Sitka spruce and Norway spruce have practically the same bark thickness.

LITERATURE REFERENCE

(1) Mattsson, L.: 'Form och Formvariationer hos Lärken.' *Medd. f. Statens Skogsförsöksanst*, xiii–xiv, 1916–17.

TABLE XXXV. *Scots Pine. Bark Percentages.*

O.B. Girth in.	*Bark percentage at different points on the stem.*									
	Breast height	*10*	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*
12	11·60	8·20	6·80	6·35	6·45	6·70	7·10	7·85	9·60	12·55
16	11·55	8·10	6·55	6·05	6·05	6·25	6·65	7·40	9·05	12·25
20	11·55	8·05	6·40	5·75	5·75	5·80	6·15	6·90	8·55	11·90
24	11·50	8·00	6·15	5·50	5·30	5·40	5·65	6·25	8·05	11·45
28	11·50	7·95	5·95	5·30	5·05	5·10	5·30	5·75	7·50	11·00
32	11·50	7·90	5·75	5·05	4·80	4·80	4·95	5·25	6·85	10·45
36	11·50	7·80	5·50	4·75	4·50	4·50	4·50	4·85	6·15	9·90
40	11·45	7·65	5·25	4·55	4·25	4·10	4·05	4·30	5·25	9·30
44	11·45	7·55	5·05	4·30	3·95	3·75	3·70	3·90	4·50	8·50

Table XXXVI. *Norway Spruce. Bark Percentages.*

O.B. Girth in.	Bark percentage at different points on the stem.									
	Breast height	10	20	30	40	50	60	70	80	90
12	6·50	6·00	6·00	6·10	6·30	6·65	7·75	9·55	11·80	16·20
16	6·05	5·60	5·55	5·70	5·95	6·30	7·00	8·35	10·90	15·35
20	5·55	5·35	5·35	5·45	5·65	5·95	6·50	7·70	10·15	14·60
24	5·10	4·95	4·90	5·00	5·25	5·60	6·15	7·20	9·40	14·00
28	4·75	4·60	4·60	4·70	4·95	5·25	5·80	6·80	8·75	13·40
32	4·45	4·25	4·30	4·40	4·65	5·00	5·60	6·65	8·25	12·70

Table XXXVII. *European Larch. Bark Percentages.*

O.B. Girth in.	Bark percentage at different points on the stem.									
	Breast height	10	20	30	40	50	60	70	80	90
12	11·05	10·55	10·40	10·40	10·50	10·65	10·95	12·05	16·20	23·50
16	10·85	10·40	10·20	10·20	10·30	10·45	10·65	11·25	12·95	19·35
20	10·60	10·25	10·05	10·00	10·05	10·20	10·30	10·75	12·05	16·80
24	10·35	10·10	9·95	9·90	9·90	10·05	10·15	10·50	11·55	15·35
28	10·05	9·90	9·80	9·75	9·80	9·90	10·00	10·20	11·15	14·45
32	9·70	9·75	9·60	9·60	9·65	9·70	9·85	10·00	10·80	13·75
36	9·35	9·35	9·40	9·40	9·45	9·55	9·65	9·85	10·50	13·25
40	9·00	9·00	9·00	9·05	9·15	9·25	9·40	9·65	10·20	12·95
44	8·65	8·45	8·50	8·65	8·75	8·90	9·05	9·20	9·90	12·70

Table XXXVIII. *Douglas Fir. Bark Percentages.*

O.B. Girth in.	Bark percentage at different points on the stem.									
	Breast height.	10	20	30	40	50	60	70	80	90
12	7·35	7·00	6·80	6·70	6·75	6·95	7·45	8·60	11·70	17·70
16	7·30	6·85	6·50	6·30	6·35	6·60	7·05	8·10	11·15	16·25
20	7·30	6·65	6·30	6·05	6·10	6·25	6·65	7·65	10·20	14·40
24	7·30	6·55	6·05	5·90	5·90	6·05	6·35	7·20	9·35	13·05
28	7·30	6·40	5·95	5·75	5·75	5·85	6·15	6·80	8·55	11·95
32	7·25	6·35	5·90	5·70	5·70	5·80	6·00	6·75	7·85	11·10
36	7·25	6·30	5·85	5·65	5·65	5·70	5·95	6·55	7·40	10·45
40	7·20	6·20	5·75	5·60	5·50	5·55	5·60	5·85	7·05	9·90
44	7·15	6·15	5·60	5·50	5·40	5·45	5·50	5·80	6·80	9·45
48	7·10	6·10	5·55	5·40	5·35	5·40	5·45	5·70	6·60	9·05
52	7·00	6·05	5·55	5·40	5·35	5·40	5·40	5·65	6·50	8·75
56	6·95	6·00	5·55	5·35	5·35	5·35	5·40	5·65	6·45	8·45
60	6·90	5·95	5·50	5·35	5·35	5·35	5·35	5·60	6·40	8·20
64	6·80	5·95	5·50	5·35	5·35	5·35	5·35	5·60	6·35	8·00
68	6·70	5·90	5·50	5·35	5·35	5·35	5·35	5·60	6·35	7·80
72	6·60	5·90	5·50	5·35	5·35	5·35	5·35	5·60	6·30	7·70
76	6·60	5·90	5·50	5·35	5·30	5·30	5·35	5·55	6·25	7·60
80	6·55	5·90	5·50	5·35	5·25	5·25	5·30	5·50	6·20	7·50

TABLE XXXIX. *Sitka Spruce. Bark Percentages.*

O.B. Girth in.	Bark percentage at different points on the stem.									
	Breast height	10	20	30	40	50	60	70	80	90
12	6·35	6·20	6·10	6·25	6·65	7·25	8·35	10·35	13·95	19·30
16	5·95	5·70	5·60	5·70	5·95	6·45	7·15	8·45	11·50	16·70
20	5·55	5·30	5·20	5·25	5·45	5·75	6·20	7·15	9·65	14·55
24	5·20	4·95	4·90	4·95	5·05	5·30	5·60	6·45	8·30	12·90
28	4·90	4·60	4·60	4·65	4·75	4·90	5·20	6·00	7·35	11·80
32	4·65	4·30	4·30	4·35	4·50	4·65	4·90	5·55	6·80	11·00
36	4·45	4·10	4·10	4·15	4·30	4·45	4·70	5·35	6·60	10·80
40	4·25	3·90	3·90	4·00	4·10	4·25	4·55	5·20	6·50	10·70
44	4·00	3·80	3·75	3·85	4·00	4·15	4·45	5·10	6·40	10·60
48	3·80	3·60	3·65	3·75	3·90	4·00	4·35	5·05	6.35	10·50
52	3.60	3·45	3·50	3·60	3·80	3·90	4·25	5·00	6·30	10·40
56	3·45	3·35	3·40	3·50	3·70	3·80	4·15	4·95	6·25	10·30

TABLE XL. *Japanese Larch. Bark Percentages.*

O.B. Girth in.	Bark percentage at different points on the stem.									
	Breast height	10	20	30	40	50	60	70	80	90
12	9·25	9·10	8·95	8·95	9·15	9·55	10·35	11·65	13·75	21·80
16	8·85	8·70	8·55	8·65	8·85	9·20	9·85	10·90	12·75	20·50
20	8·30	8·20	8·20	8·30	8·55	8·90	9·45	10·15	11·85	18·75
24	7·35	7·60	7·70	7·85	8·15	8·45	8·90	9·50	11·00	16·45
28	6·40	6·70	7·05	7·40	7·65	7·90	8·15	8·55	9·75	14·40

TABLE XLI. *Corsican Pine. General Bark Percentages.*

Bark percentage at different points on the stem.									
Breast height.	10	20	30	40	50	60	70	80	90
13·00	11·05	9·70	8·75	8·25	8·10	8·25	8·85	10·25	13·30

TABLE XLII. *Miscellaneous Species. General Bark Percentages.*

Species.	Bark percentage at different points on the stem.									
	Breast height.	10	20	30	40	50	60	70	80	90
A. grandis	4·10	3·75	3·70	3·80	3·90	4·30	5·10	6·60	9·40	16·50
A. nobilis	5·75	5·60	5·80	6·20	7·20	8·45	10·10	11·15	16·20	25·00
P. strobus	5·10	4·75	4·60	4·65	5·00	5·45	6·15	7·65	10·10	16·00
Tsuga	6·75	5·90	5·40	5·25	5·30	5·80	6·70	8·25	11·10	16·50
Thuja	8·20	7·45	7·00	6·85	7·20	7·85	8·70	9·75	12·00	17·30

(To be concluded.)

THE MANAGEMENT OF THE STATE FOREST OF RETZ, VILLERS COTTERÊTS

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INTRODUCTION.

IN his admirable article on 'The Forests of France' in vol. vi. 2, M. Oudin had so much ground to cover that he was unable to give a detailed account of the management of the forests. He gave an outline of the system of 'The Single Periodic Block' as used in the oak and beech forests, and it has occurred to the writer that it might be of interest if some details were given of its application. Among the beech forests mentioned by M. Oudin is that of Retz (Villers Cotterêts), in which the system is applied with some interesting variations from the standard practice. The writer has visited this forest more than once and made notes of the methods of working which may fill in the outline given by M. Oudin for those who have not had an opportunity of studying at first hand the operations in such a forest.

The State forest of Retz has an area of over 32,500 acres and is situated in the *departement de l'Aisne*. It lies on the plateau of Valois at a general elevation of 400 to 650 feet. The principal species are oak 20 per cent., beech 45 per cent., hornbeam 30 per cent., various 5 per cent. On the better soils the mixture of oak and beech in the proportions of 1 to 4 gives the best results, and it is the aim of the management to obtain crops of something like these proportions. Difficulties arise from two main causes. The oak has been allowed to disappear from many of the middle-aged and older woods owing to lack of proper cleaning and thinning measures, and the prolific regeneration of the hornbeam and its rapid growth in youth make it a menace to the more valuable oak and beech. The beech occupies a predominant position and regenerates well, maintaining itself against the other species except on the sandy areas; these are now being planted with conifers, chiefly Scots pine.

It is not proposed in this paper to go into the silviculture of the forest, though this presents many points of interest, but to deal with the system of management of the broadleaved high forest which forms the most important part of the whole. All that it is necessary to say about the silviculture is that the system employed is that generally known as the Compartment System of Natural Regeneration under a Shelterwood. Regeneration fellings are made in three stages: (1) the Seeding Felling, (2) the Secondary Fellings, and (3) the Final Felling. The younger woods are subjected first of all to the process of cleaning when they are about man's height, with the object of freeing the oaks from the dominance of the other species and the beech from that of the hornbeam. Afterwards regular thinnings from above are made, favouring the oak

and beech in that order, so that most of the hornbeam has been cut out by the time the woods approach the age for regeneration.

The object of management is to obtain a regular, equal, annual yield of timber and firewood, and the system employed is that known as the *Quartier bleu* with 'possibility' by volume. The system seeks to control the output of timber from the forest in such a way that, by the removal of a certain prescribed annual volume (the possibility) in the regeneration fellings, the woods are all regenerated in due course at an average age of 150 years, which is the rotation in this forest. The thinnings are not included in the possibility, but it is considered that, by following a regular system of thinning in every compartment at 10-year intervals, and so dealing with one-tenth of the area every year, the yield from thinnings will equalize itself.

The *Quartier bleu* system is a development of the older system of 'Fixed Periodic Blocks' by which the rotation was divided into a number of equal periods, say five, and blocks of woods of equal area were assigned to each period for regeneration. The first block, containing the oldest woods and occupying one-fifth of the area, was to be regenerated during the first period, whilst the other blocks were thinned. Unfortunately, it did not always happen that all the woods in the first block could be regenerated during the first period. Some had to be left over until the second, and, as time went on, the symmetry of the plan was lost. The system was too rigid, and has now given place in many forests to a system in which the regeneration block is constituted anew at each revision of the working plan. Woods already in process of regeneration, or ready for regeneration during the period for which the plan is to operate, are selected. Since there is no good purpose to be served by assigning the other woods to definite periods, there are generally only two blocks—a smaller one containing the woods to be regenerated, and a larger one containing all the rest. The woods in the regeneration block need not be contiguous. It is the practice to colour the block to be regenerated blue on the maps, hence it is referred to as the *Quartier bleu* whilst the remainder of the forest is left uncoloured and is referred to as the *Quartier blanc*.

Large forests, such as that of Retz, are divided into a number of so-called *Séries*, or Felling Series, each containing woods of all ages in the right proportions, so that for purposes of management, i.e. calculation and control of the yield, each series is treated separately and has its own *Quartier bleu* and its own possibility. The possibility of the whole forest is the sum of the possibilities of the series.

There are various ways in which the possibility can be calculated, one of which was described by M. Oudin. The method employed in the Forest of Retz is that of Duchaufour.

THE DUCHAUFOUR METHOD OF CALCULATING THE POSSIBILITY.

The compartments or woods in the series are assigned to two classes:

Class I, those whose regeneration is to take place during the period for which the working plan is made (*Quartier bleu*).

Class II, the rest of the compartments (*Quartier blanc*).

The possibility is calculated only for the *Quartier bleu* and no volume is prescribed for the other woods. The thinnings in them are regulated by area, every compartment being thinned every 10 years in the forest of Retz. A list of these compartments is made and the order in which they will be thinned is prescribed.

The calculation of the possibility is carried out as follows. The woods in the *Quartier bleu* are divided into two groups:

Group 1. Compartments in which some regeneration fellings have already been made.

Group 2. Compartments in which regeneration fellings have not been begun.

The possibility is found by dividing the total volume of the trees in the *Quartier bleu* by the 'Period of exploitation' $P = V/x$, where P is the possibility, V is the volume of the trees in the *Quartier bleu*, and x is the period of exploitation. V is found by measuring all the trees in the compartments at the time the working plan is made, with the aid of volume tables.

The period x is the period which these trees ought to last, and it should bear the same relationship to the rotation as the area occupied by these trees bears to the total area of the series. $x/R = c/S$ and $x = (R \times c)/S$, where R is the rotation, c is the area of the crops in the *Quartier bleu*, and S is the area of the whole series. Now, whilst the compartments in Group 2 are fully stocked and the area occupied by the trees in them is equal to the area of the compartments, this is not the case with the compartments of Group 1 in which regeneration fellings have begun. It is necessary, therefore, to find the actual area occupied by the trees in these understocked compartments, and Duchaufour does this by estimating the area which the trees would have occupied if they had been growing together in a fully stocked wood, which he calls the 'reduced area'. The real area of the crops in the *Quartier bleu* is then the sum of the actual areas of the fully stocked compartments in Group 2 and the reduced areas of the understocked compartments in Group 1. It has been found, by numerous measurements in the forest in question, that the average growing-space of a tree in a fully stocked wood is proportional to the square of its girth. The reduced area of an understocked compartment is therefore found by the following formula:

$$\text{Reduced area} = g^2k^2n,$$

where g is the girth of the mean tree, n is the number of trees, and k is a constant, which in the Retz forest is 5.

To calculate the reduced area of an understocked compartment, the working plans officer first of all finds the volume of the trees standing in it by means of volume tables based on girth measurements. He then divides the total volume by the number of trees, thus getting the volume of the mean tree. He then finds from his tables the girth corresponding to this volume, interpolating if necessary, and uses it in the formula. The sum of the actual areas of the compartments in Group 2, together with the sum of the reduced areas of

the compartments in Group 1 is employed in the formula for calculating the period of exploitation:

$$x = \frac{[\sum c'' + \sum g^2k^2n] \times R}{S},$$

where c'' is the area of each fully stocked compartment in Group 2.

The possibility (V/x) represents the annual volume which is to be removed to exhaust the growing stock by the end of the period x, ignoring any growth that takes place during the time. Now the period of exploitation so calculated may be less than, equal to, or greater than the period for which the working plan is to operate. In the first case the possibility will exhaust the *Quartier bleu* before the working-plan period has elapsed, in the second case the trees will just last out the period, and in the third case there will be material left uncut at the end. Where the period of exploitation is too short, it can be raised arbitrarily to the working-plan period and so reduce the possibility and build up the growing stock, or alternatively, if there are suitable compartments, the size of the *Quartier bleu* can be increased by adding them to it. Which course is adopted will depend on the condition of the forest as regards distribution of the age classes. Actually, in the forest of Retz, the period of exploitation is greater than the working-plan period (20 years) in every series, and the method is applied strictly. The effect of this will be that the whole of the trees in the *Quartier bleu* will not be cut by the end of the twenty years.

THE MARKING OF FELLINGS AND THEIR CONTROL.

It is the aim of the forest officer to cut each year the possibility in each of his series. The volume of every tree cut in the *Quartier bleu* is counted against the possibility, so that first of all he deducts from the possibility the volume of any windfalls or trees removed for other reasons during the year. He then makes any secondary or final fellings which are required for silvicultural reasons, and finally, if there is any balance of the possibility left, he makes seeding fellings which are desirable until the possibility is exhausted or nearly exhausted. A certain amount of elasticity is allowed to meet silvicultural requirements and convenience in making up lots for sale. Any excess or deficiency in the cut is carried forward to the next year. In a good mast year it may be considered desirable to make more seeding fellings than usual. The process is greatly simplified by the skill and experience of the foresters in selecting and measuring the trees and the use made of volume tables.

Marking is done with a hammer which stamps the State mark on blazes made, firstly on the bark about breast height, and secondly at the root. The latter mark remains on the stump after the tree has been felled and acts as a check on the buyer. The operation of *martelage*, as marking with the hammer is called, is carried out by two or three *gardes* and a *brigadier* under the supervision of the forest officer. The *garde* measures the girth of the tree at breast height (1·30 m.) with a calliper which reads directly in girths, estimates with

the eye the timber height to a certain diameter (22 cm. with oak, 28 cm. with beech), cuts the blazes and stamps them, and calls out the following for booking by the *brigadier*:

1. Species.
2. Girth in cm. (in 10-cm. classes).
3. Height.
4. Volume in stères.
5. If the tree is of first quality—'bon'.

The 'stère' is the stacked cubic metre and corresponds in practice to our 'cord'. The volume in stères is estimated by means of a simple formula which the *garde* carries in his head. The table of volumes is as follows:

Girth in cm.	*Volume in stères.*
60	0·25
70, 80	0·50
90, 100, 110	1·00
120	2·00
130	3·00
..	..
..	..
190	9·00
200	10·00
210	11·00
..	..

The rule is that for every tree 110 cm. and upwards, the volume in stères is found by dividing the girth by 10 and subtracting 10 from the result; e.g. 140/10—10 = 4·00 stères.

The information thus booked is used for two purposes: (1) to check the volume against the possibility, and (2) to compute the contents of the lot for sale.

(1) In order to check the volume roughly in the field, the total estimated volume in stères is multiplied by two-thirds to bring it to solid cubic metres. This is compared with the possibility to see whether any other compartment may be taken in hand, or whether there is little or no margin left. In the office the volume is calculated from tables based on girth only, actually the same tables as were used in calculating the possibility in the first instance, and booked instead of the rough estimate made in the field.

(2) For the purpose of estimating the contents of the lot and the preparation of the catalogue for the sale of the produce, the process is as follows. The volume of the *timber* is calculated for each girth class by the use of tables based on timber height as well as girth. The remainder of the material is estimated in stères by deducting the volume of the timber from two-thirds of the total estimated volume in stères. The remainder, multiplied by 3/2 to bring it back

to stères, is the volume of the small material. The proportions of the different categories of stacked wood are found by simple rules based on experience.

It will be seen that the actual work of measurement and calculation is reduced to a minimum. This is possible, of course, only by reason of long-continued working, and the collection of statistics which have enabled volume tables and rules for estimating contents and assortments to be compiled.

The lots marked are sold standing in October, and the buyer is allowed one year for felling and another year for the removal of the produce. All the large trees have their tops lopped before felling, in order to minimize the injury done to the remainder of the trees and the young growth, and also to reduce the liability to splitting of the stems themselves. Fines are inflicted for damage done to standing stock. One of the conditions of sale in seeding fellings is that the buyer must eradicate holly, which, in some of the compartments, forms a hindrance to regeneration.

The thinnings in the compartments not in the *Quartier bleu* are marked and sold in two different ways, according to the size of the material. Thinnings in the older woods are marked with the hammer and treated in the same way as the regeneration fellings, except that they are not controlled by the possibility. Thinnings in the younger woods are marked with a scribe and sold 'by unit of produce'. After the material has been felled, cut up, and stacked, it is measured and sold by auction. A tariff is prepared giving standard prices for each class of material—logs, pitwood, firewood of different categories—and the buyers bid for the lot a percentage above or below the standard according to quality. This arrangement enables the management to make a supplementary thinning, if the compartment seems to require it, after the trees originally marked have been cut.

The chief points in which Duchaufour's method differs from others are: firstly, the possibility is fixed for the regeneration fellings only; secondly, the period over which the block is expected to be regenerated is fixed in relation to the size of the block, not the size of the block fixed in relation to a prescribed period; and thirdly, the real size of the block is determined by making allowances for the deficient stocking of the partially regenerated compartments. During the period in which the working plan is expected to operate, the possibility is extracted each year, but the whole of the block is not necessarily exhausted during that period. There is therefore more elasticity in the selection of areas to be cut, and the intensity of the cutting, than where the total possibility of the period is expected to exhaust the growing stock. On the other hand, the accuracy of the method depends on the validity of the basic assumption that the mean growing-space of a tree is proportional to the square of its girth, for all sizes of trees within the usual limits of the age-classes concerned. Obviously this can only be ascertained by a careful and systematic collection and examination of statistics. Moreover, the method is only suitable where the arrangement of age-classes is approximately normal. Where this is not the case, a modification has to be introduced, which may take the form of a lengthening or shortening of the period of exploitation, or of adding to

or excluding from the *Quartier bleu*, compartments on the border-line of exploitability. In the conditions which prevail in the forest of Retz, the method appears to work well.

SUMMARY.

(1) A brief description is given of the Forest of Retz (Villers Cotterêts), the main part of which is beech-oak high forest worked under the Compartment System of Natural Regeneration.

(2) An account is given of the *Quartier bleu* system of management, with Duchaufour's method of calculating the possibility.

(3) The operation of marking fellings and the use of the measurements obtained, for the purposes of management and sale of produce are described.

(4) Some of the characteristic features of Duchaufour's method are briefly discussed.

SCOTS PINE IN MORAYSHIRE AND STRATHSPEY[1]

BY W. H. GUILLEBAUD

THE following paper is based for the most part on observations made during the Society's Excursion in May 1933, when the following areas were visited: Teindland Forest near Elgin, the property of the Forestry Commission; Darnaway Forest near Fŏrres, the property of the Earl of Moray; and woods on the Countess of Seafield's estates round Grantown in Strathspey. The writer felt some diffidence in preparing, on the basis of a tour lasting only a few days, an article under such a comprehensive title, but it is hoped that those with greater knowledge who may read the paper will make due allowances. Acknowledgements are due to the Forestry Commissioners for permission to publish sample plot and other data used in the paper. On behalf of the members of the Society thanks are also due to Mr. A. Warren of Teindland Forest, to Mr. W. Munro and Mr. M. Feaks of the Darnaway Estate, and to Colonel J. Grant Smith and Mr. Gilbert Brown of the Seafield Estates for their generous hospitality and for their readiness in imparting information on the woods under their respective charges.

TOPOGRAPHY.

The northern slopes of the high ground between the lower reaches of the Spey and the Moray Firth provide one of the most heavily wooded districts in the whole of the country. The preponderating species is Scots pine, although there are considerable tracts of oak and other hard woods, usually not of very high quality, and confined for the most part to the Old Red Sandstone formation which fringes the coast. The average elevation of the pine woods is not high, i.e. about 500 to 600 feet above sea-level, and only occasionally do the stands run up over the 1,000-foot contour. Slopes are gentle to moderate and the country is rather lacking in bold features.

The country round Grantown, in contrast to the coastal woodland belt of Morayshire, is more definitely mountainous, the elevation of the valley-bottom is over 600 feet, and the woods run up to 1,500 feet above sea-level. Scots pine is even more characteristically the tree of the country than in Morayshire. Farther up the Spey the ancient forests of Rothiemurchus and Abernethy provide remnants of the natural Scots pine which must at one time have occupied very extensive areas in this part of Scotland. The high ground to the south and west affords a considerable amount of shelter for the woodlands in Strathspey, and the timber-line can probably be pushed higher here than in most other hill districts in Scotland. Owing to heavy glaciation during the Ice Age the hills are rounded and the slopes usually moderate; the woods are

[1] This was the subject of study during the Society's Excursion, May 1933.

confined largely to the slopes, flat areas are either used for cultivation, or, in the upland districts, owing to lack of drainage, have developed into *Calluna-Scirpus* moorland.

CLIMATE.

Along the Morayshire coast the mean annual temperature is 46° F., the mean maximum 53° F., and the mean minimum 39° F. Severe frosts are of rare occurrence, and the sea-coast is noted for its mild winters. The rainfall is from 25 to 30 inches per annum. The nearest official meteorological station to Grantown is at Kingussie, about 20 miles to the south-west. Here the mean annual temperature is 44° F., the mean maximum 51° F., and the mean minimum 37° F., that is, approximately 2 degrees colder than the coastal regions of Moray. The rainfall at Grantown averages 31 inches, and much snow falls during the winter months.

GEOLOGY.

The solid geology divides the district into two unequal portions: there is a strip of Old Red Sandstone rocks from 5 to 10 miles in width fringing the the coast of Moray, with an inlier of Trias round Lossiemouth. Both the upper and lower series of the Old Red Sandstone are well represented, and outcrops of the basal conglomerate have also been traced. Inland the great series of the Metamorphic schists, slates, and grits occupies most of the area. These schists are very complex and have not yet been fully worked out. They vary greatly in composition, those rich in mica often providing very fertile soils; the poorest types contain almost pure quartzite, and the soils are then very deficient in plant nutrients. Some at least of the schists round Grantown are believed to be micaceous in composition.

Both the Old Red Sandstone and the schist formations are overlaid by a variable but usually considerable depth of glacial deposits. It is probable that these deposits are derived in large measure from the underlying rock and thus vary in quality with the composition of the latter. As a rule the rock is overlaid by boulder clay, typically a more or less sandy clay or a loam, containing many rounded stones and boulders. In many places the boulder clay is covered by a subsequent deposit of water-borne sandy or gravelly drift, and it is this drift which in most cases provides the actual growth medium for the trees. Where the layer of drift is thin the roots may penetrate to the boulder clay below.

Around Grantown the surface deposits appear to consist largely of loose pebbles and gravel embedded in a more or less loamy sand, the proportion of stones rapidly increasing in the lower levels of the soil. Soil pits showed a profuse development of roots down to a depth of at least 2 feet. The Darnaway deposits, also on the Moine schists and gneisses, appeared very similar. The glacial deposits at Teindland on the Old Red Sandstone were rather different; here there was a variable depth of what appeared to be fluvio glacial drift overlying extremely compacted boulder till. The till was dark purplish-red in

colour, very full of broken or rounded pebbles and boulders, and consisting of the usual mixture of sand and clay particles. The worst conditions for tree growth were found where drift was absent and the trees were growing upon the weathered boulder till.

For the most part the forest soils of the area belong to the great group of podsolized soils, i.e. the surface layer has been leached out, and the dissolved material redeposited at a lower level in the so-called zone of deposition below which rests the unaltered drift or parent rock. As a whole, the degree of podsolization in the area visited was not intense and the depth of the leached layer relatively thin, rarely exceeding 6 inches. The principal exception was the upper part of Teindland (Findlay's Seat), where the soil was intensely podsolized though the depth of the leached layer was found to vary greatly in the soil pits examined. A thick, hard, iron pan was found here and appeared to be continuous over the greater part of the area. Over the rest of the Teindland area hard pan appeared to be quite sporadic, although the underlying drift or till was often hard and relatively impermeable. At Darnaway and round Grantown on Speyside as a rule the deposition layer was quite soft and evidently did not present any serious obstacle to root penetration, judging by the large number of tree roots in the lower layers of the soil.

VEGETATION.

Floristically, the three areas differed considerably. In Speyside the dominance of the *Vaccinia* (*Vaccinium Myrtillus*, *V. Vitis-idaea*) and *Empetrum nigrum* give a characteristic appearance to the vegetation of the pine woods. Below these shrubs was usually a luxuriant growth of *Hylocomium* and *Hypnum* mosses, the whole bearing a strong resemblance to the better *Vaccinium* and *Oxalis myrtillus* types of central Sweden. The graceful *Trientalis europeus*, *Anemone nemorosa*, and *Listera cordata* give an added charm to the woods.

Although this is perhaps the most characteristic Speyside type under Scots pine, other types occur, as, for example, in the large Revack Wood near Grantown where the dominant vegetation was grass (*Agrostis* on the lower slopes and *Aira flexuosa* on the upper) with luxuriant *Hylocomium* mosses; *Vaccinia* were present but played a subordinate role. The small Twayblade (*Listera*), woodsorrel, *Trientalis*, and *Anemone* occurred in patches throughout the wood.

Relatively little *Calluna* was seen in the woods visited in Speyside, though it would presumably become dominant generally if the woods were cut over and left unstocked with trees. One wood, however, Balnagown, about 70 acres in area, was shown to the party, in which *Calluna* was dominant in association with Juniper and the *Vaccinia*; here the growth of the pine was slower than in any of the other woods visited.

On the upper slopes of Darnaway Forest, where the elevation is less than 500 feet above sea-level, *Calluna* becomes the dominant plant under the older pine stands, with subordinate *Vaccinium Myrtillus* and *V. Vitis-idaea*, and *Aira flexuosa*. Some young plantations were seen, possibly on better sites, where the vegetation was mainly grass—*Aira flexuosa*—with *Oxalis*, *Trientalis*,

and *Anemone*. One feature, noted as common to both Darnaway Forest and the Speyside woodlands, was the prolific regeneration of Rowan (*Pyrus aucuparia*), which in places was coming up thickly in gaps among the older Scots pine.

The whole of the Teindland area consists of felled Scots pine woodland, replanted during the last 8 years mostly with Scots pine; there are patches of scrubby pine still standing on the poorer ground, but the conditions here are not typical of the area as a whole. In the absence of pine stands approaching maturity it is not possible to make a direct comparison with Darnaway Forest or the Speyside woodlands. Under the present conditions heather is the dominant plant, although on the better slopes it does not form a continuous cover but occurs in patches or clumps with intervening grassy patches of *Aira flexuosa* with luxuriant *Hylocomia*. Other plants occurring more or less frequently are gorse, broom, *Trientalis*, *Arctostaphylos*, *Goodyera repens*, &c. Patches of raspberry occur in places. There are one or two fairly extensive peat bogs on Teindland composed of black spongy peat carrying a vegetation which in its undrained state consisted chiefly of cotton grass (*Eriophorum vaginatum*) growing among large cushions of tufted sphagnum. The drainage of these bogs has dried them to a remarkable extent, the sphagnum has died out, and the cotton grass become much less prominent. Heather is now the dominant plant, with cotton grass and *Polytrichum* moss locally abundant where the drainage has not been fully effective. Towards the top of the hill at Teindland a different and much poorer type of land occurs; here, as already mentioned, the podsolization is relatively intense and the underlying boulder till very hard and compact. The vegetation varies considerably; where there is any appreciable degree of slope, heather and lichen are the dominant and almost the sole plants present. On the flatter ground which occupies most of the area heather is dominant but in a weakly unhealthy state of growth, and associated with it are abundant lichen (*Cladina*), *Scirpus caespitosus*, and Carnation Sedge (*Carex panicea*). Other species are *Juncus squarrosus*, *Erica Tetralix*, and *Carex binervis*. Grasses are virtually wanting, except where basic slag has been applied to the soil after ploughing.

GROWTH AND FORM.

The outstanding feature of the district from the silvicultural point of view is the preponderating part played by Scots pine. Only the valley of the Dee can compare with it for extent of virtually pure pine forest. How far the dominance of this species is really conditioned by the soil conditions, climate, &c., of the district is rather a moot point. There is a good deal of evidence (e.g. the almost invariable predominance of European larch where it occurs in mixture with Scots pine in Strathspey) which suggests that the conditions in many places are quite favourable for other conifers, notably European larch and Norway spruce. On the other hand, Scots pine is the native conifer of the district and has also undeniable merits as a first crop, or pioneer species, on the heathery or bilberry-covered soils typical of the moorlands of the

district, and no doubt the local foresters, whose reputation has always been deservedly high, were not slow to recognize this fact. It may be that now that the second—often the third—crop is being harvested, more efforts might be made to locate the suitable sites for earlier maturing species than Scots pine. There are some interesting tracts of mixed oak and conifers planted on the southern (Old Red Sandstone) half of Darnaway Forest, but for the most part the soil is neither deep enough nor sufficiently rich to produce good quality oak timber, and a considerable proportion of the hardwood is under conversion to Scots pine.

The relatively small amount of birch in the district was remarked during the excursion, especially round Grantown. In places rowan (*Pyrus aucuparia*) appeared to be taking on the role of birch as an invader of gaps in the pine woods, but no old rowans were noted in the mature pine stands. The pine stands are even aged, being the product either of planting or of natural regeneration by the shelterwood compartment system; they often contain a sprinkling of European larch, and occasionally also of Norway spruce.

The majority of the pine woods in Strathspey originated from seed collected in the natural forest of Abernethy. According to Mr. Gilbert Brown, there were two distinct types in the old trees in this forest, the one with drooping branches, and the other with short, sturdy, horizontal branches but with pendulous points. Both types appeared to be equally resistant to snow break. Other characters are: the short needles which are retained on the twigs for 4 to 5 years, and the flattening-out of the crowns at the relatively early age of 100 years. The scales of the bark in old trees are very large but somewhat dull in colour. The dead branches are remarkably persistent on the stems, the trees in dense unthinned stands of 40 to 50 years of age still carrying many dead branches near ground-level. In Curr Wood near Nethybridge about 10 per cent. of the trees differed from the remainder in having red stems—due to the thin bark extending downwards nearly to the foot of the trees; these thin-barked stems were markedly cleaner than those with thick bark, and they had as a rule narrower crowns.

The Morayshire pine appeared to differ from the pine in Strathspey chiefly in the longer retention of the conical form of the crowns in old age. One 30-year-old pine stand at Darnaway was very variable in type, the bigger trees being often coarsely branched; the records indicate that the plants were raised from seed partly of native and partly of southern European origin.

Before the War large areas of mature stands of Scots pine were to be found in the district. Some of these stands were remarkable for fast growth as well as for high volume production; for example, a sample plot measured during the War in a 126-year-old stand at Orton, near Elgin, showed the growth to be of Quality Class I, the mean girth at breast height was 5 feet, the height 92 feet, and the volume per acre 12,000 cubic feet. Another plot of first quality was measured on the Altyre Estate, east of Darnaway; the age was 72 years, height 70 feet, girth 45 inches, and volume 9,000 cubic feet per acre. The average rate of growth of 38 plots measured in the district was, however,

somewhat below the mean of the second-quality class, and all except 7 of the plots were less than 500 feet above sea-level. Very few of the plots came from the Strathspey area.

Some fine old Scots pine were seen during the excursion in Darnaway Forest and near Castle Grant. One of the biggest trees girthed 10 feet 7 inches at breast height, was over 100 feet in height, and 40 feet to the first branch. The age was said to be about 150 years, but as Pressler borings showed about 70 rings in the last 2 inches of radius, the tree may have been somewhat older (Plate IV).

NATURAL REGENERATION IN STRATHSPEY.

The Seafield Estates have a special interest for British foresters because they provide the only example in the country of natural regeneration of Scots pine carried on systematically over a long period of years and on an impressively large scale. The method employed, the shelterwood compartment system, appears to be well adapted to the locality conditions. As soon as the woods have opened out sufficiently to allow grass to appear, sheep and cattle are turned in to graze; the stock keep down the heather and other ericaceous plants and churn up to some extent the needle humus with the mineral soil. When the trees are approaching maturity and the stocking has been reduced, either naturally or by thinning, to about 200 trees per acre, a seeding felling is made in which half the trees are removed, the next felling again removes 50 per cent. of the trees, leaving 50 trees per acre; after the third felling 15 trees are scheduled to remain to be removed when the area is more or less completely restocked. The length of the regeneration period depends upon local conditions, but may be almost indefinitely prolonged where new growth is slow in appearing.[1]

When the old crop contains an admixture of larch, the latter is often the first species to appear, the pine seeding later in the gaps among the larch and under the crowns of the mother trees. The Tom an Uird Wood, 1,030 acres in area, provides an interesting example of successful larch regeneration. About 470 acres situated on the north slope of the hill were placed under regeneration about 50 years ago. The old crop was Scots pine and larch in about equal proportions. The fellings covered a period of about 17 years, and during the early stages of the work the larch seedlings came up thickly over a considerable part of the area and resulted in a pure crop. Where the soil was not at once receptive for larch the pine seeded itself in the later stages of the regeneration, and these areas are now composed of pure pine.

In Strathspey the pine, in youth at least, is able to tolerate a very considerable measure of shade. The seedlings germinate freely under the mother trees, and if the latter are left to stand will grow up into their crowns without showing any indication of undue competition.

It seems feasible to associate the free regeneration of both pine and larch in Strathspey with the high winter snowfall, the snow often persisting until

[1] From information kindly supplied by Mr. Gilbert Brown, Woods Manager to the Seafield Estates.

the seeds are ready to germinate. Lack of snowfall in other parts of the British Isles may in part explain the scarcity of natural regeneration which we have so often cause to bewail.

ARTIFICIAL REGENERATION.

Although natural regeneration of Scots pine has been so successful in Strathspey the greater part of the forestry of the district is based upon planting with nursery-raised stock. For this seed is always collected from some of the many fine stands in the locality. There is a well-constructed seed kiln at Darnaway, and both this estate and Seafield collect all the seed they require from their own woods. The most favoured type of pine plant is the two-year-one transplant, although one-year-two's are also used by Mr. Feaks on the Darnaway Estate and one-year-one's at Teindland.

The nursery practice is of a high standard; in particular special attention is given to the regular introduction of a cleaning crop. This is of such general importance that the following details may be of interest. At Darnaway potatoes and turnips are used as a cleaning crop and give better results than lupins and tares, which are also sometimes used for the purpose. At Teindland the practice is to sow a mixture of 1½ cwt. of oats and 1¼ bushels of field peas per acre. Before sowing the land is dressed with 2 cwt. of Kainit and 2½ cwt. of superphosphate per acre; the growing crop is top-dressed with ammonium sulphate at the rate of 1¼ cwt. per acre. Potatoes are also grown as a cleaning crop; these are manured with 1½ cwt. of sulphate of ammonia, 3 cwt. of superphosphate, 1¼ cwt. of steamed bone flour, and 1¾ cwt. of potash salts per acre. Transplant lines always follow the potato crop. At Darnaway the blow-lamp is used to burn the surface of the seed-beds, the lamp being applied a week to 10 days after the pine seed is sown and covered.

The usual planting distance for Scots pine is 3½ by 3½ feet at Darnaway and 4 by 4 feet or 4½ by 4½ feet on the Seafield Estate and at Teindland. The straight notching-spade is the standard tool for pine planting, but at Teindland the semicircular spade has been used latterly for planting pine and larch and has given excellent results on the somewhat tightly packed soil of this forest. The method employed is as follows: after inserting the spade in the ground the handle is lowered and the tool swung from side to side several times until the soil is thoroughly stirred and a low heap of worked soil accumulates. A form of mound-planting with local cultivation is thus secured; this is especially useful on badly drained soils, and here it is the practice to add additional soil to the heap.

TREATMENT OF YOUNG STANDS.

The thinning, and also, to some extent, the regeneration practice in Strathspey are in great measure determined by the economic conditions of the district. Distances from road and rail are often quite formidable, and cost of haulage combined with the heavy railway freight to the nearest large centres of consumption makes the disposal of small sizes or small lots of timber virtually

impossible. In consequence it has long been the practice to rely entirely on the natural thinning out of the young stands until the trees have reached about sleeper size, i.e. have a breast height quarter-girth of 10 to 11 inches. This means that for 60 to 80 years the trees have to fend for themselves, and, as the evidence on the ground showed, do so remarkably well. An excellent illustration of this was provided by the 260-acre block of 50-year-old natural Scots pine known as Curr Wood near Nethybridge (Plate V). Regeneration in this wood was both rapid and complete, and there is scarcely a gap in the area. In many places the seedlings came up less than 1 foot apart, and in the thicket stage the wood was virtually impassable. It has been predicted for the last 20 years and more that the crop would be entirely ruined unless it was immediately thinned, but the subsequent history has falsified this as it has so many other predictions in forestry. Much the same remarks apply to the large stand of natural larch in Tom an Uird Wood; here again the young stand was extremely dense and tending was apparently confined to the removal from time to time of dead trees, and yet the present 40-year-old crop is an exceptionally fine larch wood in appearance.

In the case of the Curr Wood pine and in most of the other pine woods in Strathspey squirrel damage has probably played a certain part in assisting the natural process of selection. All the middle-aged pine woods in this district have suffered extensive damage from squirrels when in the small-pole stage. Hardly a tree has escaped some damage, and the proportion of trees which have lost their tops at one time or another must be very high. In recent years determined efforts have been made to keep the squirrel numbers down, and these have been largely successful. One effect of severe squirrel damage, leading to the loss of the upper part of the tree, must be to break the canopy and allow neighbouring unattacked trees space in which to develop their crowns and ultimately, in many cases, to suppress their injured competitors. At the present time, although the crowns of the dominants are somewhat small and often one-sided, there is quite a wide girth dispersion in the crop, and in general the natural reduction in the stem numbers appears to be proceeding satisfactorily.

The Forestry Commission have a set of four sample plots in Curr Wood. Of these one has been thinned lightly (B grade), only dead, dying, and suppressed trees being removed. This plot acts as a control to the remaining three plots, all of which are now thinned to a so-called D grade, which represents the heaviest possible type of low thinning. The object in having three similarly treated plots is to obtain some measure of the range of variation inherent in sample-plot work of this type, i.e. the plots constitute a form of uniformity trial. These plots have been twice thinned and measured and are due for a third measurement in 1935.

An extract from the summarized data relating to two of the plots is given in the table on p. 145.

When the plots were taken in hand at the age of 44 years there was the very heavy stocking of over 1,700 trees per acre, apart from large numbers of dead trees which were not counted. The light thinning has reduced these to the

Scots Pine—Curr Wood, Strathspey.

Plot number and thinning grade.	*Year of measurement.*	*Age of crop.*	*Main Crop.*				*Thinnings.*				*Current mean annual increment per acre over last 5 years.*
			No. trees per acre after thinning.	*Mean height.*	*Mean girth at 4′ 3″.*	*True volume per acre.*	*No. trees per acre.*	*Mean height.*	*Mean girth at 4′ 3″.*	*True volume per acre.*	
		years.		ft.	in.	cub. ft.		ft.	in.	cub. ft.	cub. ft.
69. B grade (light low thinning)	Aug. 1925	44	1,310	39	16½	2,420	410	31	10½	160	..
do.	Sept. 1930	49	1,190	42	18	3,330	190	35	12	135	183
70. D grade (heavy low thinning)	Aug. 1925	44	1,110	40	17	2,360	645	32	11½	420	..
do.	Sept. 1930	49	665	42	20	2,300	445	35	17	885	165

present figure of about 1,200 per acre, while in the heavy thinning the number now stands at about 650 stems per acre. The volumes removed in thinnings are 300 cubic feet from the light thinning and 1,300 cubic feet from the heavy thinning; at the same time the standing volume has been slightly diminished in the D grade plot, while the B grade shows a substantial increase. Such a thinning as has been made in the D plots (still more so in the B plots) is uneconomic under present conditions owing to the poor demand for poles of the size cut, but it will be interesting to observe the effect of the heavy thinning upon the growth of the remaining trees, and in particular to determine whether the heavy thinning will yield saleable timber at a substantially earlier age than the lightly thinned control plot.

It appeared to some members of the excursion that a crown thinning in which only competing dominants were removed might prove the best method of dealing with the crop at the present stage, and it is hoped to add a crown-thinned plot to the series in 1935. It is to be feared that even this method will not produce saleable produce unless market conditions alter materially in the meanwhile.

Another interesting wood in the vicinity of Grantown is Revack Wood, most of which consists of a 50-year-old pole stand of pine with a sprinkling of European larch and also some Norway spruce near the foot of the hill. The stand was formed by planting and not as a result of natural regeneration. The wood rises to the considerable elevation of 1,450 feet, but the trees in the upper part show remarkably little signs of exposure and height growth is well maintained even at the top of the hill. The vegetation is largely grass, *Aira flexuosa* and some *Agrostis*, with subordinate bilberry and *Oxalis*. The soil is a sandy loam with a typical leached profile. A feature of the wood was the extremely bad squirrel damage, and all the trees appeared to have been attacked and many that had been ringed had lost their tops. In spite of the relatively high elevation there was no indication of snowbreak, apart, that is, from the fallen tops of trees obviously ringed by squirrels. The stand had never been thinned and contained many dead and dying trees which, together with the squirrel damage, gave the plantation a very ragged, uneven appearance. In spite of this there seems to be sufficient good trees to make a fairly satisfactory final crop. The larch scattered through the Scots pine had not been damaged by squirrels and were strongly predominant, averaging about 10 feet taller than the pine. Near the top of the wood, larch of 12 and 13 inches quarter-girth are to be found, while the surrounding pine barely girth 8 inches quarter-girth. Spruce, where these occur, equally stand out above the pine; the economic value of the crop would obviously have been increased if larch and spruce had formed a higher proportion of the original stand.

During the excursion some attention was given to the condition of the humus under the dense middle-aged stands of pine in Strathspey. It was significant to find that though the humus was, generally speaking, of the raw humus type, it was not densely matted but loose, often intermingled with grit, and seldom as much as 4 inches in depth. This may be taken to indicate com

paratively rapid decomposition of the needle humus and good mobilization of its contained nitrogen. While the absence of birch or other soil-improving species is perhaps to be regretted, there is no evidence in Strathspey of any serious soil deterioration resulting from the continued stocking with pure pine.

In a discussion after the excursion the question of pruning was raised. It is the practice on the Darnaway Estate to prune the young pine to a height of 9 feet, but the general view of the members of the Society was that considerably higher pruning—up to 20 to 30 feet—would be desirable. In this matter much depends on the use to which the timber will eventually be put. With the relaxation of the somewhat rigid Post Office specifications for telegraph or transmission poles, a large part of Scotland's requirements for these poles might be met from the woods in this district, but early pruning of well-shaped trees should help greatly to increase the proportion of poles useful for this purpose. As regards convertible timber, the technical qualities of the Scots pine from this district are unquestionable, but there is no disguising the fact that the lumber is more knotty than the slower-grown pine from the Baltic countries. This is a defect which could be quite well overcome by pruning, and there seems no reason whatever to suppose that clean-grown Scots pine from this part of Scotland could not produce high-grade joinery material in the future.

DISEASES, PESTS, AND INJURIES.

Scots pine has an unenviable but usually well-deserved reputation of being a prey to a greater number of enemies than any other conifer. The Scots pine in Morayshire is no exception in having such pests as blackgame, capercailzie, roe deer, and above all the pine weevil to contend with. Where new plantations are formed adjoining recently felled pine woodland the weevil is often extremely troublesome and can only be kept in control by intensive trapping. A somewhat elaborate form of trap is used at Teindland; a hole is dug and short pine billets placed at the bottom; these are covered with small branchwood and finer twigs with needles placed on top. By way of contrast with many pine areas in the south, damage done by the pine-shoot moth (*Evetria*) appeared to be quite negligible. Pine beetle (*Myelophilus*) was also remarkably little in evidence.

The Seafield woodlands are particularly interesting from the point of view of insect damage. According to the commonly accepted theory of clean forestry one would expect to find pine beetle, at least, multiplying in the numerous dead and dying trees in the younger stands and to see evidence of beetle damage in the living crowns. The woods are, however, conspicuously lacking in signs of such damage, and this suggests that the natural predators and parasites of the beetle have achieved a satisfactory measure of control. It is also interesting to note that, according to Mr. Gilbert Brown, pine weevil does scarcely any damage to the natural regeneration in spite of the fact that the mother trees are gradually removed, leaving a succession of fresh stumps on the area. Even in the pine plantations on the Seafield Estate the weevil

does not appear to be the pest that it is in Morayshire. It is hoped that the evidence provided by the Seafield woodlands as to biological control will shortly be investigated by a forest entomologist.

A little of the stem form of *Peridermium* was noticed in some young pine at Darnaway, but otherwise there was remarkably little evidence of fungal diseases in the district.

The absence of signs of snowbreak in the older pine woods in Strathspey is remarkable having regard to the heavy winter snowfall common in this area. Even at the top of the Revack Wood the only snowbreak observable was in trees whose tops had been ringed with squirrels. The absence of this form of damage is presumably correlated with the type of pine (short elastic or drooping branches) and is a good illustration of the importance of racial type in Scots pine. On the other hand, snow damage to the upper edges of woods on slopes with rising ground behind is very extensive. Mr. Gilbert Brown stated that a belt as wide as 100 yards along the upper edges of the woods is virtually ruined as a result of snow slipping down from above. The fact that this form of damage is almost as severe at, say, 1,100 feet elevation on a slope rising to 1,800 feet, as it would be at 1,300 or 1,400 feet, suggests that it is better policy to fix the planting line on a slope on the high side of the presumed limit rather than too low, the width of the margin lost to economic production being about the same in both cases.

Mention has already been made of squirrel damage in the pine woods of Strathspey; this has been shockingly prevalent in the past, and but for the conservative thinning practice and the great density of the stands would have been even more disastrous than is actually the case. Even so the injury to the growth and quality of the timber has been very great. With the present utilization of the mature timber mainly for railway sleepers, internal defects are not so serious as if it were used for constructional or joinery purposes, but if in the future market conditions improve and there is an outlet for higher-grade material, the defects caused by the squirrel damage may be a most unwelcome factor.

AFFORESTATION EXPERIMENTS AT TEINDLAND.

The Research Branch of the Forestry Commissioners has been carrying out experiments since 1925 on the afforestation of a block of very poor moorland at the top end of Teindland Forest, known as Findlay's Seat. The ground was planted some 70 years ago with Scots pine but without any adequate drainage; the crop here developed into mere scrub from 5 up to 15 feet in height which was left standing when the rest of the wood was cut during the War. The soil and vegetation have already been described in the earlier part of this paper, and it is sufficient here to remind readers that this is a type of *Calluna* moorland characterized by weakly heather with *Scirpus* and Carnation Sedge, and with an abundance of lichen below and between the heather tufts. The soil is a heavily leached compacted boulder till derived from Old Red Sandstone Conglomerate. A usually thin skin of fibrous peat overlies the mineral soil.

Not only is the soil impermeable but, owing to the slight degree of slope, natural drainage conditions are very poor.

Land of this kind has a certain value as a grouse moor, but in its natural undrained condition the poverty of the heather must make it relatively poor even for this purpose; certainly, if it were possible at a reasonable cost to afforest this type of land successfully, a substantial gain to the national wealth of the country must result. A further ground for investigating the tree-growing capacity of this land is that patches of a similar type of ground not infrequently occur here and there among better land the planting of which is not in doubt. It is obviously desirable to know whether such poor patches should be left severely alone as unplantable or if they can be so treated as to grow timber and thus avoid the necessity for leaving unplanted banks amongst a tract of woodland.

The experimental approach to the problems presented by this type of land is (1) to determine which are the most important factors likely to be involved; (2) to lay down over a succession of years a series of carefully thought-out field plots, each series being designed to throw light on one or more of the presumed factors; (3) as soon as positive results show in any part of the work to extend at once along the lines indicated; (4) if the results are sufficiently promising to lay down trials, using the approved method, on a semi-field scale so that some idea of the cost of the work may be obtained. This form of approach has been more or less closely followed out at Teindland. The crucial factors were considered to be (*a*) the bad surface conditions and the unaerated state of the soil, (*b*) the poverty of soil, and (*c*) the selection of the species which would accommodate itself best to these adverse conditions.

In applying the field-plot method due regard was paid to the important question of lay-out, controls (untreated plots) were provided, and as far as possible a random arrangement of replicated treatments and controls was adopted. In this, as in almost every other kind of field-plot work, replication is essential, as little or no reliance can be placed on results based on a single pair or series of plots.

Work was started at Teindland in 1926, and chief attention was given at first to the problem of aerating the soil. Two hypotheses were considered: the first that it was essential to break up the impermeable pan layer below the leached surface soil, and the second that this was unnecessary and that the solution of the problem lay in breaking up the surface layer. In both cases it was considered that ploughing would probably be required, with subsoiling to break the pan in the first case, and without subsoiling in the second. The soil was so compact and full of boulders that it seemed doubtful whether the use of any sort of plough was possible. However, a cheap two-horse plough and a subsoil plough were purchased and preliminary trials made. Both implements worked better than had been anticipated and two experiments were carried out, the first to compare the effect of single-furrow ploughing, the furrows spaced at 6 and 12 feet apart and subsoiled, against similar ploughing without the use of the subsoil plough. Scots pine were planted at 3 feet apart

along the drains and between them. The second experiment was on the utility of the ploughs for making drains as compared with hand labour. In the same year several small-scale intensive experiments were carried out to compare species of pines, namely, Scots pine, mountain pine, and *Pinus contorta*, the two latter being species which are fairly tolerant of bad drainage conditions, and were also considered the least exacting as regards mineral-food requirements.

In the following year it was decided to proceed on a bigger scale with the ploughing work. A new type of three-horse plough was specially constructed and proved effective, breaking up the surface soil to a depth of 5 to 6 inches. A large-scale experiment was laid down to test the following methods: (1) two furrow strips 3 feet apart, subsoiled after the surface ploughing; (2) two furrows 3 feet apart without subsoiling; (3) complete ploughing without subsoiling. One-half of the area was planted in the same year (1927) with a variety of species, i.e. Scots pine, *Tsuga heterophylla*, *Thuja plicata*, *Picea omorica*, Norway spruce, Sitka spruce, and a mixture of Norway spruce with mountain pine and of Sitka spruce with mountain pine. Other field experiments in this year included direct sowing with Scots pine and Norway spruce—this was not a success owing largely to frost-lift—and a small-scale test of the effect of skimming off the covering layer of peat from the mineral soil with no disturbance of the mineral layer, as against similar removal of the peat but mounding up the mineral soil in preparation for planting. *Pinus contorta* was planted but has not done nearly as well as on ploughed ground or on mounds prepared without skimming off the peat. This result suggests that, poor though the surface peat appears, when it is aerated by ploughing or mounding it does break down to yield nutrients for the young trees.

A mixture of Sitka spruce and *Pinus contorta* was planted on land ploughed in strips. The pine has done well, but the spruce are still in a state of check. Japanese larch was planted on mounds with a direct notch control, but has done badly so far. In the same year, 1928, the trial was made of sowing the seed of certain leguminous plants, perennial lupin, gorse, and Spanish broom on the ploughed ground, the object being to improve and enrich the soil. The seeds germinated, but the plants failed to develop properly. Further plots of different species were planted on the ground ploughed the previous year.

In the following year, 1929, it was decided to persevere with the plough work as this was obviously a suitable method of improving the physical conditions of the surface layers of the soil. A new three-horse plough was constructed with some improvements on the last and proved very successful. Six acres of ground were ploughed with it, using two methods, namely, (1) complete ploughing of strips 10 feet wide with 10-foot intervals unploughed between, the plough strips only to be planted; and (2) ploughing in three-furrow strips spaced at 5 feet from centre to centre. The species planted was *Pinus contorta*. A new departure was made in the same year by Dr. Anderson, who introduced a group method of planting. This consists of the hand-digging of localized patches 7 feet square and at 15 feet from centre to centre. These patches

were planted each with a closely spaced group of 13 plants. The cost of the preparation amounted to £3 11*s.* 6*d.* per acre. The species used were Scots pine, *Pinus contorta*, and mountain pine.

A preliminary trial with artificial manures was carried out in 1929. It had already been found that basic slag stimulated to a marked extent the growth of trees planted on the poorer types of peat. Whether it would be equally effective on the leached morainic soil of Findlay's Seat was uncertain, but it was worth trying in view of the poverty of the soil. In 1930 basic slag was used on a much larger, though still experimental, scale. Alternate sections of the large ploughing experiment were dressed with basic slag at the rate of 10 cwt. per acre, and slag was also applied to many of the new experiments, leaving the usual unmanured controls.

During the last three years, 1931–3, further land of the same type was taken in, ploughed, and used for trials of different species, e.g. Sitka spruce, Japanese larch, birch, *Alnus oregona*, and *A. incana*. The birch and alder, if successful, may play a useful part in improving the soil conditions in admixture with conifers. Field plots have also been laid down in recent years to test plants of *Pinus contorta* raised from seed of different sources from British Columbia.

The above account describes in brief the development of the field experimental work carried out since 1926 on the Findlay Seat area. The experiments total over 50 in number and cover an area of some 30 acres; it is not possible here to give more than a general indication of the scope of the work. The results also can only be dealt with very briefly. The earliest plots to be laid down are only 7 years old and the majority of the more interesting experiments are still younger. It follows that at this stage only tentative conclusions can be drawn. The division of the problem into three main aspects, envisaged when the work started, appears to have been justified and it will be convenient to consider the results under these heads.

(*a*) *The Bad Surface Conditions and Unaerated State of the Soil.* The evidence is very strong that the conditions can be greatly improved by intensive drainage and by mixing up together the surface-peat layer with the mineral soil below. Plants growing along the sides of the drains are twice as tall as those between the drains, while ploughing or hand-digging have had an equally unmistakable effect. Whether it is essential to break through the pan layer is a point that cannot be decided as yet. So far the plants are growing as well on ground that has been merely surface-cultivated as on ground which has been subsoiled. Having regard to the fairly considerable depth of soil over the pan, the opinion is ventured that surface cultivation combined with deep drainage will be sufficient to give satisfactory tree growth.

(*b*) *Poverty of the Soil.* The response of all species to an application of basic slag is the most striking feature of the Teindland experimental area. Even when the ground has been drained and ploughed, growth remains slow during the first 5 years or more after planting. When slag has been given, as a rule there is no response in the first year, but in the second year the needles are often double the length of those on unmanured plants, the colour is a deeper

green, and shoots of up to 6 inches may be put on. The subsequent development varies with the species; the manured pines retain their good colour for the most part and continue to make much more vigorous growth than the controls. The spruces, on the other hand, are now, 3 to 4 years after manuring, very yellow in colour, in fact somewhat yellower than the controls, though still putting on good leading shoots. The same phenomenon has been observed with manured spruce on some types of peat, but as a rule the yellowing has been only transitory. Hemlock spruce in the large ploughing experiment responded strongly at first to the manure, but at the present time the plants have become somewhat ragged through loss of foliage and do not look too promising. The *Thuja* have responded well to slag and the colour, in May 1933, was much greener than that of the controls. The tallest Sitka spruce noticed was in a slagged plot on ploughed ground, planted 1928, the height was 5 feet 2 inches, and the plant had put on a 22-inch leading shoot in 1932. This was exceptional, but there were many plants which had put on a 12-inch shoot. Whether the stimulus produced by the slag will be permanent remains to be seen; an important point to be noted is that the manure has had a marked effect on the vegetation as well as on the trees, bringing in grasses such as *Agrostis* and *Holcus*, and improving the vigour of the heather.

(*c*) *Choice of Species.* The behaviour during the first 5 years in the life of a tree does not necessarily give much of a clue as to its ultimate growth or economic value, and the present order of success may be changed in 10 or 20 years time. At the moment *Pinus contorta* appears the species best adapted to the conditions; next follow Scots pine, Sitka spruce, and *Thuja*. Mountain pine is healthy but slow-growing as usual. Norway spruce and *Picea omorica* are inferior to Sitka spruce. *Tsuga* is not thriving well though it made a good start. Japanese larch has not been given a sufficient trial, except in the most recent experiments, but does not appear promising.

SUMMARY.

The chief points of interest noted during the excursion of the Society of Foresters to certain woodland areas in Morayshire and Strathspey were:

(1) The *Vaccinium*-rich vegetation in Strathspey has a marked resemblance to similar forest types in Scandinavia.

(2) The soils are usually podsolized but typically with a good depth of permeable drift overlying the boulder clay. Iron pan is of only local occurrence and generally not continuous. Pine roots were frequently found penetrating the lower layers of the soil.

(3) Very poor soil and vegetation conditions were seen at Findlay's Seat in the upper part of Teindland Forest where a previous crop of Scots pine and larch planted about 70 years ago had failed: experimental work on afforestation is now being undertaken by the Forestry Commission.

(4) Success of the natural regeneration of Scots pine and larch in Strathspey obtained by the Shelterwood Compartment System, also relatively the shade-

Scots pine, about 150 years old, near Castle Grant, Grantown-on-Spey.
Vegetation: *Vaccinium myrtillus*, *V. vitis-idaea*, &c.

An old Scots pine (in centre) near Castle Grant. Girth at breast-height 10 feet 7 inches, age 150 to 200 years

PLATE IV

Curr Wood near Nethybridge. Naturally regenerated Scots pine 50 years old, unthinned, with 1,500–2,000 trees per acre

Sample plot in same wood. Thinning grade: Light Crown Thinning. 670 trees per acre, mean height 42 feet

PLATE V

bearing nature of the pine which comes up freely under the crowns of the mother trees were noted.

(5) The local market conditions in Strathspey make early thinning uneconomic and delay the first opening out of the stands until 60 to 70 years. In spite of this delay the trees have segregated out well, and although the stands are very dense the dominants are mostly well developed. The unthinned Tom an Uird natural larch wood was particularly interesting from this point of view. The wood is now 40 years old, carrying 1,500 to 2,000 trees per acre, but remarkably free from whips in the upper canopy.

(6) The healthy condition of the younger pine stands in the district, especially in Strathspey, the small amount of damage due to pine beetle, and the rarity of the pine-shoot moth were points of interest. The small amount of damage by pine beetle is particularly interesting in view of the unthinned state of the woods and the consequent presence of many dead and dying trees which might be expected to harbour the beetle. It is suggested that predators and parasites may be in control of the pest in these woods.

(7) The younger pine woods are relatively branchy, and the dead branches persist for many years on the stems. The introduction of pruning is suggested.

(8) The very severe damage has been caused to the pine by red squirrels in Strathspey. Over 90 per cent. of the trees may show signs of squirrel damage with serious injury to as many as 50 per cent. of the trees. The squirrel damage is now much less serious.

(9) The form of the Scots pine in Strathspey appears to be particularly well adapted to withstand heavy snowfall. There is very little evidence of snowbreak in the woods, although winter snowfall is heavy in the average season. At about the age of 100 to 120 years the crowns flatten out and become dome-shaped.

(10) Many of the Strathspey soils appear suitable for growing of larch. The larch is almost always dominant where it occurs singly in mixture with Scots pine.

(11) Good growth of pine and larch was seen at relatively high elevations, for example, in Revack Wood near Grantown, where the pine was 40 to 50 feet high and single larch up to 65 feet high at 1,400 feet above sea-level.

(12) Very fine 150- to 200-year-old Scots pine were seen at Darnaway and near Castle Grant in Speyside; there were many trees of great size and perfect form. Volumes of up to 10,000 cubic feet quarter-girth per acre have been measured near the coast in Morayshire.

(13) The field-plot experimental work on the poor land at Teindland was inspected. The work done to date suggests the importance of intensive drainage and of surface cultivation. A specially constructed plough has given excellent results. Of the various species tried, *Pinus contorta* appears to be the easiest to establish, and to start into growth most readily, but both Sitka spruce and Scots pine are very promising. The growth of all species is greatly stimulated by the application of basic slag either at the time of planting or as a top dressing a few years after planting. The amounts applied varied from $3\frac{1}{2}$ to 10 cwt. per acre. It is too soon to give a final verdict as to the lasting effect of these slag applications.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION, LEICESTER, 1933

MAJOR THE HON. RICHARD COKE was Chairman of the Department of Forestry, K*, and Dr. E. V. Laing, Secretary.

The following is a list of authors and titles of papers:

'A System of Forestry for the British Isles', Major the Hon. Richard Coke.

'Factors affecting the Propagation and Rate of Growth of *Salix caerulea*', Lt.-Col. E. Pratt.

'Trees and the Countryside', Mr. William Dallimore.

'Good Forests and Thinning', Mr. H. Mundt.

'Some Effects of Thinning in Coniferous Plantations', Mr. James Macdonald.

'The Utilization of Thinnings', Mr. A. P. Long.

'Forestry and Sport', the Hon. Nigel A. Orde-Powlett.

'An Account of recent Experimental Work on Mycorrihiza in Relation to Forestry', Dr. M. C. Rayner.

'Preliminary Results from Peat Planting Experiments at the Lon Mor Experimental Station', Mr. J. A. B. Macdonald.

'Public Opinion in the Empire on Forestry', Mr. W. A. Robertson.

SOCIETY'S AND OTHER NEWS

SEVENTH ANNUAL GENERAL MEETING

The Council have decided that the next Annual General Meeting be held in conjunction with the 6th Annual Excursion. As at present proposed, it will take place at Kew on Thursday, 24 May, next.

ELECTION OF OFFICE-BEARERS

As there is no competition for any of the vacancies there will not be a ballot this year, and those nominated will be elected at the next Annual General Meeting. Sir Alexander Rodger will become President and Mr. W. L. Taylor Vice-President. The Editor, Business Editor, Secretary and Treasurer, and Auditor will be re-elected. Messrs. John D. Sutherland, W. H. Lovegrove, and James Macdonald will be elected Councillors for two years.

SIXTH ANNUAL EXCURSION

Preliminary arrangements have been made to hold the next Annual Excursion in the London district, with head-quarters in London at which the party will assemble on the evening of Wednesday, 23 May (the Opening Day of Chelsea Show). On Thursday, Kew Gardens will be visited and the 7th Annual General Meeting held. Bedgebury Arboretum and Forest Garden and Rothamsted Station will be included in the programme for the next two days, the excursion terminating on the afternoon of Saturday, 26 May. The final arrangements will be communicated to members by circular in due course. The Council hope that the combination of Excursion and Annual General Meeting will result in a larger attendance at both.

CORRECTION

It is regretted that the legend of the text-figure on page 46 of vol. vii, No. 1 was wrong. It should read as follows:

Zone in which capillary stream is dominant. ||
,, ,, percolating ,, ,, =
,, of intensity of interaction and initial horizon formation. #

ELM DISEASE IN GREAT BRITAIN

A further survey to determine the course of elm disease in this country was carried out recently by Mr. T. R. Peace of the Imperial Forestry Institute, Oxford, on the instructions of the Forestry Commissioners. Three counties have now to be added to the list of those in which the disease is known to occur, namely, Durham, Derbyshire, and Dorset. The characteristic symptom of elm disease, namely, die back of the crown, appeared this year rather earlier than usual, and by the end of July so many cases were seen that a heavy attack appeared probable. Surprisingly few further cases, however, developed during August and September, and the final result may be stated as showing a definite increase over 1932 but a decrease as compared with 1931. The number of apparent recoveries noted this year was still quite large, but in one case trees which for three years had shown no external signs of the presence of the disease have again begun to die back.

The general position is unchanged from that of previous years. The disease remains

serious in parts of the eastern counties. But even here really severe damage is of quite local occurrence as may be judged from the following counts made during the course of the survey along certain roads in Essex.

Locality.	*Length of road examined.*	*Number of Elms counted.*	*Percentage dead.*	*Percentage diseased.*
Newport . .	4½ miles	307	24	22
Audley End . .	2½ „	119	0	14
Wickford . .	8 „	689	1	3

In the south midlands and in the south-eastern counties of England the disease is frequent but seldom serious. Towards the west and north the disease is quite sporadic and it has not been found north of a line between Durham or Chester, in the western counties of Wales, or in Cornwall. Having regard to the dry summer of 1933 it may be considered satisfactory that the disease has not spread more rapidly or done a larger amount of damage than appears to be the case.

An interesting observation made during the course of the survey relates to the condition of the elms in the north of England and in Scotland. Many of the older trees, mostly Wych Elms, were found to be in a distinctly unhealthy condition, showing signs of die back closely resembling those caused by the elm disease but distinguished from the latter by the absence of the characteristic markings in the twigs and by one or two more general characters such as the browning of the leaves round the edges. The cause of the trouble, which is quite widespread, is under investigation.

Forestry Commission.

30th October 1933.

THE SOCIETY OF AMERICAN FORESTERS

The President of the Society of American Foresters extends to any Foresters who may be in the United States a very cordial invitation to attend the 33rd Annual Meeting of the Society, which is to be held in Milwaukee, Wisconsin, from December 28 to 30, 1933.

REVIEWS

Studies of Scottish Moorlands in relation to Tree Growth. Forestry Commission Bulletin No. 15. H.M. Stationery Office, 1933. Price 2*s.* 6*d.*

Review by A. S. Watt

IN his impressions of British vegetation formed during the International Phytogeographic Excursion of 1911, F. E. Clements regards peat and its vegetation as the major problem facing the British ecologist. Since then various contributions have been made, but no one has faced the peat problem as a whole and in its several parts. Even this cannot be claimed for this bulletin, but it deals more comprehensively with peat as an ecological problem than any previous work in this country. The size and complexity of the task demand an equipment of scientific knowledge and ability usually shared by a team of workers but happily combined in Dr. G. K. Fraser of the Forestry Department of Aberdeen University, who brings a keen observation of plant behaviour and an expert knowledge of soil to bear upon factors affecting the growth of trees. Moreover, peat and the climate associated with it is not always an ideal medium in which to work.

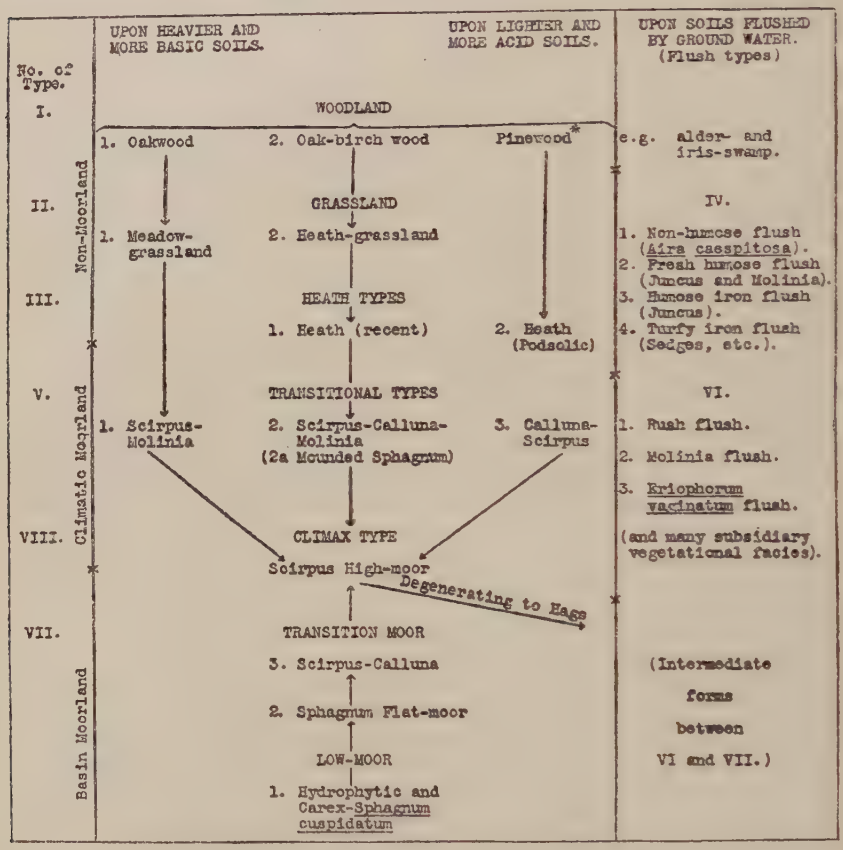
Indiscriminate planting of peat in the west of Scotland had met with some success and much failure. The immediate problem confronting the forester is to distinguish plantable from unplantable peat, to devise methods of making the unplantable profitably plantable, and—a refinement for the future—to assess in cubic feet per acre the productive capacity of the peat for a given species. The first part of the problem has been answered: as to the second, diligent inquiry into cause has thrown overboard some suggested methods of ameliorating peat and has revealed exactly in what peat types practicable measures are successful.

The term moorland is used in the restricted sense of vegetation characteristic of peat soil: peat as a soil has an organic origin and character and a high-water table at or near the surface. The abundance of water may be due to climatic factors (in climatic moor), chiefly a high rainfall fairly evenly distributed throughout the year and a low evaporation, or to a topography holding up the drainage (basin moor). Basin moor may begin (low moor) on acid or basic peat, although the final stage (high moor) in both is acid. Climatic moor, on the other hand, develops on stable soil in the oceanic climate of cool temperate regions and is found both at low and high elevations where the requisite climatic conditions exist. The peat plants which flourish under these conditions accentuate the oxygen deficiency: this in turn accelerates peat formation. Thus the soil becomes progressively less well aerated with development. The process can be reversed by removing a primary cause: from the topographically determined basin moor, at least in areas of relatively low rainfall, the excess water may be removed by drainage: climatic moor cannot (so far as the experiments have gone) be ameliorated in this way.

In Scotland three regional types of climatic moor are recognized: (*a*) Scirpus Moor characteristic of the west and north-west, dominated by *Scirpus caespitosus* with co-dominant *Calluna* of poor and open growth; (*b*) Calluna Moor predominating towards the north-east has *Calluna vulgaris* dominant and *Eriophorum vaginatum*—which may become dominant after burning—as its chief subsidiary; and (*c*) Molinia Moor with *Molinia coerulea* dominant prevails in the south of Scotland. Each of these is correlated

with the different climates of the three regions although Molinia Moor in the south may be a stage in development to Scirpus Moor.

Scirpus Moor is specially dealt with in the bulletin, although the other vegetation types leading up to the climax or characteristic of local conditions are also described. The bulk of the field work was carried out at Inverliver, Argyllshire, typical of the rainy equable west coast. The surprising fact is brought out that in deep peat the temperature



at a foot depth remains stable throughout the year at 44° to 44·5° F., while the temperature change at the surface of the peat from night to morning may be great and intensify the effect of frosts which are frequent in the early growing-season. The area is exposed. The mineral soil types display the effects of the oceanic climate, strong leaching and reduction: creep soils being unstable are less affected.

The accompanying scheme, reproduced by permission of the Controller of H.M. Stationery Office, summarizes the types of vegetation at Inverliver and their relationships. The central type is the climax—Scirpus Moor (VIII); the other types, whether they begin as woodland on mineral soil or as vegetation floating on water, form series progressing towards it. Local deviations from the types due to flush water are indicated in the right-hand column. Each of the types is briefly characterized and its relationships explained. Transitional types as well as the climax type of climatic moor are widespread throughout the west and the north-west of Scotland.

As to the peat itself, three main types corresponding with the three moorland types of Scotland as a whole are recognized: (*a*) pseudo-fibrous peat characteristic of the west and north-west, (*b*) fibrous peat characteristic of the east and north-east, and (*c*) amorphous peat characteristic of the south of Scotland. The first two are structural, i.e. the plant remains are identifiable, but whereas in (*a*) chemical change in the complete absence of oxygen leads to a loss of strength and tenacity, in (*b*) these properties are retained in the scarcely altered plant remains. In (*c*) the peat shows no recognizable plant tissues. All three are found in the west of Scotland, with pseudo-fibrous peat as the prevailing type and fibrous and amorphous peat transient (seral) or local. The two last respectively change into and are overgrown by pseudo-fibrous peat.

The detailed consideration, based on a large body of experimental data, of the chief soil properties in relation to tree growth cannot be adequately summarized here, but the importance of water and aeration and the relation between the two is substantiated: the considerable horizontal and vertical variation in pH values and the lack of correlation with tree growth dismiss acidity as a factor of major importance: the determination of the lime requirement 'is a distinctly more satisfactory method of comparing the relative quality of adjacent peat types than pH value, and that therefore lime-requirement is of more importance in relation to tree growth on peat, than actual acidity': and the highly interesting conclusion is reached that 'no element of nutrition can be said to be present in the poorer kinds of peat in such small amounts as to limit the growth of trees, with the possible exceptions of phosphate and available nitrogen', and these by improved aeration should exist in adequate amount. The discovery of the factors limiting to tree growth narrows the field of experimental amelioration: improved aeration should follow. Field and laboratory experiments designed to effect this either directly by ditching or indirectly by altering the texture of the peat, thus facilitating water movement and oxygenation are described and the results analysed. The author's main conclusion is that 'with few exceptions, ordinary ditching is quite ineffective in producing aeration, while, upon deep scirpus peat, even deep ditching may produce little improvement after many years. The rate of water-movement through pseudo-fibrous peat is so very slow that steps must be taken to break down its gelatinous structure. This may be accomplished by chemical ameliorants which, however, can act effectively only where the ameliorant and the peat are thoroughly mixed together. Basic slag is the most satisfactory ameliorant as, in addition to its direct action, it indirectly decomposes the peat to amorphous humus by providing suitable conditions for bacteria.'

Because Sitka and Norway spruces have a wider range of tolerance of peat soils than other species tried, Dr. Fraser uses their rate of growth as an index of site quality. Check is attributed to want of proper aeration and the consequent restriction of the roots to the surface turf where available food material is deficient and where they are subject to fluctuations in weather conditions, temporary waterlogging, frost, and insolation. Once out of check the spruce growth varies and in a general way the rate of growth decreases with the approach to the climax on which the growth is scarcely measurable.

Of great importance to the forester as also in the wider fields of plant ecology and land utilization is the section devoted to the effect of long-continued heather burning and grazing upon the moorland vegetation of the west of Scotland, in which it is shown how the former widespread practice of grazing and burning have destroyed much national wealth by converting more valuable vegetation, including forest, to moorland. To rebuild the waste places Dr. Fraser lays stress upon the proper mechanical cultivation of the surface peat combined with draining and manuring. This is assisted by the use of knowledge of the effect on the soil of different kinds of plants. Some degrade the soil,

others improve it, and the area of plantable peat is gradually extended by the influence of 'improving' species.

This bulletin is so packed with details that the general argument only can be outlined, but there is much valuable information incidental or ancillary to the main issue. The appendixes include a number of helpful photographs, vegetation charts, and a particularly useful N/S map of Great Britain. The reproduction of Map 1 is bad.

The Forestry Commission and Dr. Fraser are to be heartily congratulated on the issue of an excellent piece of work.

Enquête internationale sur les Incendies de Forêts. The International Institute of Agriculture, Rome, 1933. Pp. 418 and Appendixes.

Review by W. L. Taylor

THE inquiry, the results of which are recorded in this publication, arose out of a resolution in regard to forest fires by the World Forestry Congress held in Rome in 1926. To give effect to the resolution the International Institute of Agriculture issued a comprehensive *questionnaire* in 1927 to which 72 States and Forest Authorities responded, including the principal British Dominions and Colonies, but not including Great Britain. Very full particulars of the results obtained are given together with explanations, bibliographies, and summaries of the conclusions drawn. A chapter is devoted to each of the thirteen principal heads of the interrogatory which runs the full gamut from causes, principal and secondary, to the nature and extent of the damage suffered, precautionary measures, fire-fighting organization and methods, propaganda and education, legislation and insurance.

As to causes, it is said that by far the greater number of the forest fires throughout the world are the result of carelessness on the part of persons traversing the woods or working therein; malicious fires are the exception; outbreaks from natural causes are rare, and, apart from lightning, often open to doubt. Lightning accounts for a considerable number of fires in Canada and the United States, and up to 50 per cent. of the recorded forest fires in British Columbia over a period of years are laid to the score of the god Vulcan. That hardy perennial as a causative agent, broken glass, is referred to in the returns from one country only (Belgium).

The inquiry confirms the fact that forest fires are a phenomenon of all countries and climates. The hazard of fire exists for every kind of forest whatever the climatic conditions may be; the danger is more or less serious according to species and the age of the stand. Conifer forests of the younger age classes are the most liable to destruction and risks diminish, generally speaking, with the advancing age of the woods. The most harmful effects of a forest fire do not manifest themselves until after the lapse of time. Forest soils damaged by fire may, for a long period, be incapable of regenerating normally and naturally. Where fire repeatedly ravages a forest, marked and lasting changes are effected in local ecological conditions, with the result that the processes of restocking with valuable species may be long delayed in consequence of fundamental modifications of the surface soil and vegetation. Such changes can affect vast territories effecting changes in local topography, climate, fauna, and flora. The abrupt halt which fire can cause in the biochemical processes of the upper layers of the soil is to be considered as a typical form of damage attending all severe forest fires. Forest soils on the steeper slopes robbed of their litter and humus may be subject to conditions of rapid erosion, always adverse to reafforestation, while in the more level areas the normal processes of forest

soil formation are rudely interrupted. These results, which are very similar in all countries, have attracted specialist attention with the aim of establishing principles of fire protection based on scientific knowledge of the phenomena, but this research although ably prosecuted is yet far from complete. These phenomena are not easily observed and independently interpreted. Attention is particularly drawn to the present lack of systematic research into many of the points arising. Little is known of the general laws which govern the spread of forest fire, a matter which requires investigation apart from influences due to variation of external conditions. Indirect damage to the forest is in need of careful study, and preliminary research into measures of protection have not taken sufficiently into account the natural defensive resources of the forest itself in the way of biological reactions to external dangers, though modern silviculture does tend towards management on stricter ecological principles. Fire protection is to be sought by simple economic and lasting means. Up to the present there has been much evidence of empiricism; elementary methods of prevention have been in use which have proved feeble as a permanent defence against the risk. Careful supervision, the strictest care of fire in the forest, and the disposal of accumulated litter are all of undoubted value. Less certain is the value of such temporary operations as the burning of herbage and brushwood or the making of fire traces. Authorities are not agreed as to the efficacy of these works. As, however, in spite of all precaution, risk of fire cannot be excluded, a trained personnel becomes a necessity, organized rapidly to notify outbreaks of fire and to assemble a fire-fighting force on the spot in the shortest possible time. Speed is of first importance. It is unfortunate that imperfect knowledge has marked the development of fire-fighting, and in these circumstances it is dangerous to speak of tactics and technique. If it is possible to establish definite principles based on scientific or strategic knowledge of the problem it is likely that the most economic form of protection will prove to be development of an organization aimed at the immediate extinguishing of all fires in the forest before they can spread, but this is, of course, a policy of perfection.

It is agreed that present procedure does not vary greatly and those countries which are subject to disastrous forest fires already possess organized systems for combating outbreaks. The most advanced services lay down the following rules:

(*a*) Subdivision of the forest into fire zones.
(*b*) Maintenance of a permanent staff under a director of fire-fighting.
(*c*) Fostering an intelligent utilization of local resources as to water and means of communication.
(*d*) Careful choice of personnel.
(*e*) Modernization of equipment.
(*f*) Legal protection for the officer in charge.

The nature of the organization should be influenced by that of the forest property to be protected. Methods should be more strict in the case of communal forests and areas subject to communal rights. One hundred and forty-three pages are devoted to a résumé of the various existing codes and forest laws concerning the prevention of fires and protection of the forest from fire damage, and information is given of the legislative measures of 46 different countries and States.

The development of forest insurance is retarded in most countries for want of adequate preparatory work. To establish coefficients of the local risks, elaborate and reliable statistics are indispensable. Without this aid, relations between the companies and the forest proprietors cannot be sufficiently elastic. There is, however, considerable activity in the field of mutual forest insurance. This method is likely to make rapid strides, especially in those countries in which forest ownerships are much divided, and when

risks are fairly uniform and easy to determine. It is held that the matter of forest fire statistics is not given the consideration it merits.

All those who are interested in the protection of forests from fire are asked to consider the advantages to be reaped by the appointment of a conference of experts to discuss a plan of research applicable to all countries. Such conference should consider the following points:

1. The facts concerning the origin and development of forest fires.
2. The limits of existing research.
3. Examination of silvicultural measures useful as aids to the inducement of natural resistance to fires.
4. Methods of registration of the results of systematic research.
5. Information concerning the forest services, forest research stations, centres of study, &c., which would collaborate in research.
6. The co-ordination, compilation, and publication of information obtained from the various lines of research undertaken.

It is urged that means of defence against a universal and growing peril are of interest to all, and should be supported by all nations in whose internal economic policy forestry takes part.

The volume is well arranged, well written, and clearly printed and contains a great deal of detailed subject-matter of particular as well as general interest to all who are concerned with the protection of the forests from the most ruthless of all its enemies excepting only *Homo sapiens* and his destructive exploitation. The plea for support should not be disregarded by British foresters, much of whose work is, from the circumstances of the case, particularly exposed in its earlier stages to the hazard of fire.

Meria laricis, The Leaf Cast Disease of Larch. By T. R. Peace and C. H. Holmes. Oxford Forestry Memoir, Number 15, 1933. 28 pages; 4 plates.

Review by W. R. Day

FOR many years past one of the bugbears of those who raise European larch in nurseries has been the leaf cast caused by *Meria laricis*. Nevertheless, although the fructifications and mycelium of the fungus have been described for systematic purposes with the result that it has already received more than one name, no attempt to give a comprehensive account of its biology, or of methods by which it can be controlled, has been published until the issue of this Memoir. In Great Britain the larch is one of the most important of the conifers and this disease is, without exception, the most serious affecting this species in the nursery. No one who has seen beds of seedlings that have suffered from a really serious attack by *M. laricis* will have any doubt as to this. The authors of this Memoir are, therefore, to be congratulated in having made a real contribution to our understanding of the biology of the fungus, and also in having demonstrated that by timely spraying with a suitable substance the infection may be effectively controlled.

A number of interesting points arise out of the work. Thus the authors are able to confirm the dependence of the fungus on humid conditions, and especially upon a low rate of evaporation for infection and spore production. That the rate of evaporation is not of necessity directly dependent on the humidity of the air is a matter of great importance in connexion with the spread of this disease. Then there is the resistance of the fungus to low temperatures, its consequent power of overwintering on suitable

material, and in connexion with this the great importance of the green or partly green needles, which hang on young larch throughout the winter, as the principal centres from which the infection spreads in the spring. The discovery of this brought out the importance of early spraying in the control of the disease and this was made possible when the fungus proved to be susceptible to sulphur sprays. As with the oak mildew investigated by Woodward, Waldie, and Steven (*Forestry*, vol. iii, No. 1), one cannot overstress the importance of taking this disease in time and destroying the primary sources of infection. If this is done there cannot be any doubt that effective control can now be obtained.

Anzucht gesunder Pappeln- und Aspenpflanzen. By J. Liese, *Forstarchiv*, 1931, pp. 108–11, and 1933, pp. 111–15.

Review by W. R. Day

THIS paper is concerned with the development of decay in poplars as a result of faulty propagation. As is well known, poplars are usually propagated in one of three ways, namely, by cuttings 8 or 9 inches long and of about the thickness of a thumb, by longer cuttings or sets of larger size and with the head of branches left on so that the young tree never has to form a new leading shoot, or by root suckers. The easiest method of producing a large number of plants is by the use of short cuttings, providing the species will regenerate in this way. Liese points out that certain faults are liable to occur if this method of propagation is used. In the first place a number of shoots arises from the cutting, and of these one has to be selected and the others pruned off or a group of stool shoots and not a single stemmed tree will develop. Then also the shoot that has to be selected frequently arises some way down the cutting and not from the tip; this necessitates a further pruning operation or a dead snag is left which takes some time to heal over and which becomes colonized by decay-causing fungi. He points out that even if the greatest care is taken the cut surface of the cutting, both at its top and in the soil at the bottom, is very liable to be infected by wood-decaying fungi, and that the zone of protecting wood, impregnated with wound gum and with heavily thylosed vessels which forms across the cut surface, is often unable to prevent their entry. Because of this he is in favour of using cuttings of moderately small size, that will rapidly heal over at the ends, and is of the opinion also that it is really much better to use a set, which retains its head of branches, and which because of this is not liable above ground to develop the faults that are almost unavoidable if short cuttings are used. The aspen, because of the ease with which it produces root suckers, is commonly propagated by means of these. He says that it is not uncommon to find that these suckers arise from a decayed root, that sometimes the decay in the root has affected the wood of the sucker, and that this decay is perpetuated in the heart of the tree. He therefore recommends the discarding of any suckers that show any signs of such decay.

It does not appear from the paper to what extent Liese has checked his statements about decay originating from the infection entering cuttings at places where the wood is exposed. Nor does it appear that any determination had been made as to the proportion of trees of felling size that are appreciably affected by decay that has entered in this way. This is a not unimportant point. For example, Schmitz and Jackson (1) investigated heart rot in *Populus tremuloides* in Minnesota. The trees were naturally regenerated by means of suckers, and they found that none of the heart rot could be traced to decay entering the tree from the decayed root of the parent tree. The writer's experience with the Cricket Bat willow also suggests that it is easy to lay too much stress

on the importance of the small wounds that inevitably occur when regenerating trees by means of cuttings or sets, as a means of entry for heart-rotting fungi. Schmitz and Jackson found that branch stubs were the principal means by which decay-causing fungi (chiefly *Fomes igniarius*) entered the trees; fire scars and insect wounds playing a subsidiary role. This probably applies equally well to the European aspen, *P. tremula*. Eklund and Wennmark (2) found that in Sweden *Armillaria mellea* was important as a cause of heart rot in aspen. This fungus first causes a rot of the root, as is well known, and would be associated with the tree at a later stage of its development than during the first year or two after planting.

One feels, therefore, that it is easy to lay too much stress on the importance of fungal infection at the cut surfaces of a set or cutting. Nevertheless care in cultivation is certainly most desirable, and not the least in that part of cultivation which is concerned with propagation and with the care of the young tree. Some of the more important uses of poplar wood, e.g. plywood, chip-baskets, matches, make it desirable to produce a wood that is very free from faults and, as has been abundantly proved in connexion with the Cricket Bat willow, the key to the production of clean faultless wood is to be found in the care given to the trees during the first few years of their life. Observations made throughout this country show that at present poplars usually receive but scanty attention during these critical years. Inquiries made recently over a large area of England showed that one of the most important reasons for this is that estate owners find that there is no good market in most localities for poplar. Whether a wider search or better marketing organization would find this to be untrue is a matter of considerable interest and importance. It is, however, quite certain that the scrupulous care in propagation, such as Liese desires, and as is certainly necessary for the production of really clean timber, will only be given when the growers feel that a market is available giving prices which sufficiently repay the cost of such trouble.

LITERATURE REFERENCES

(1) H. Schmitz and W. R. Jackson, *Heart rot of Aspen*, University of Minnesota Agricultural Experimental Station, Technical Bulletin, No. 50, August, 1927.

(2) S. Ekland and G. Wennmark, 'Några Undersökninger av aspskog', *Skogsvards Föreningens Tidskrift*, 1925, xxiii, pp. 80–104.

Les Essences forestières exotiques en Suisse. Par H. Badoux. *Mitt. Schweiz. Centralanstalt f. d. forstl. Versuchswesen*, xvii (2), 1932.

Review by the Editor

EXOTIC trees are not important in continental Europe, except in Denmark, but increasing attention has been paid to them in recent years in Switzerland under the advocacy of Professor Badoux. This article gives notes, including sample plot data where available, on a number of them, coniferous and broadleaved, including Green and Blue Douglas fir, *Abies grandis*, *Picea pungens*, Sitka spruce, *Picea Omorika*, Lawson Cypress, *Thuja plicata*, *Cryptomeria japanica*, Japanese larch, Austrian pine, Weymouth pine, *Quercus rubra*, and *Populus canadensis* Moench.

Douglas fir is highly thought of in Switzerland, in contrast to its present unpopularity in this country, particularly in Scotland. It has been used at the lower and middle altitudes, namely, 1,500 to 2,000 feet, and it has surpassed all other species in volume production, while its timber is considered to be of excellent quality. Data from a number of sample plots are given, and these indicate that its growth in Switzerland is

similar to that in this country. Total heights of 80 to 100 feet have been attained in 45 to 50 years, and volumes of 8,000 to 10,000 cubic feet quarter girth per acre. Blue Douglas fir has been used to a smaller extent at the higher altitudes. Its future is considered encouraging provided *Rhabdocline* does not become a serious disease.

Abies grandis, which has given good results in Normandy, the Cévennes, and elsewhere in France, has been tried to some extent in Switzerland. A sample plot near Lausanne showed good growth and volume production, namely, a mean height of 86 feet and a volume per acre of 7,500 cubic feet quarter girth at 38 years. It is not yet known what the quality of its timber will be.

Of the spruces, *P. pungens* has shown some promise at the tree limit in the Alps. For example, there is a small plantation at Sur Chaunt near St. Moritz in the Engadine at an altitude of over 6,000 feet. The growth although slow, namely, a maximum height of about 20 feet in about 25 years, is much greater than in the indigenous species, such as larch, spruce, and Mountain pine. Sitka spruce, which is the most popular exotic in this country at present, has not attained much success so far in Switzerland. It has not been extensively tried, but such trials as have been made have not been particularly successful.

Some data are given for Lawson Cypress, and *Thuja plicata*. In a sample plot of the former a mean height of almost 70 feet and a volume of 4,000 cubic feet was attained at 41 years. Less is known regarding *Thuja*, but it is considered that it may have a future at the lower elevations.

Japanese larch and *Cryptomeria* have not yet been sufficiently tried to determine their possibilities.

Austrian pine is prized because of its good growth on dry poor soils, and as a nurse for more valuable species. As in central Europe generally, Weymouth pine was used on some scale and considered a valuable species. It is interesting to note that it is considered that early and frequent thinnings have appreciably reduced the effects of the Blister Disease.

The article is illustrated by a number of good photographs.

NOTICES

Thirteenth Annual Report of the Forestry Commissioners for the Year ending September 30th, 1932. H.M. Stationery Office. Price 9*d.*, plus postage.

IT is stated that the year under review marks the transition between the large programme approved in September, 1929, for the decade 1929–39, to the reduced five-year programme to which reference was made in the last Annual Report. During this period the sum available for expenditure on all purposes will be an Exchequer Grant of £450,000 per annum plus working receipts, estimated to make a grand total of £600,000. This will permit a planting programme of 20,000 acres, the acquisition of sufficient land to keep intact the reserve required for maintaining the planting programme, a limited programme of forest workers' holdings, the provision of grants for planting on the same scale as during the last three years, and the carrying on of research and assisting in forestry education.

The reduced programme has necessitated the destruction of nursery stock of an estimated value of £50,000 at cost price.

81,933 acres were acquired of which 46,437 were classified as plantable. The area

planted during the year was 22,663 acres, making a total of 211,674 acres, of which 198,759 acres consisted of conifers, and 12,915 acres of hardwoods.

There is a progressive decline on the area planted by grants to local authorities and private owners; the figures for 1930, 1931, and 1932 were 6,702 acres, 5,932 acres, and 5,180 acres respectively.

The research activities of the Commissioners include work on the stratification of seed with sand prior to sowing, weed control in forest nurseries, and the use of sand and grit for covering small-seeded species. The reassessment of plantation experiments on difficult soils shows that on the whole satisfactory progress is being made. Reference is made to the favourable influence of basic slag on Japanese larch on a relatively bad type of shallow peat in the west of Scotland. In five years the trees closed up to the extent of forming a canopy in places. An investigation into the pruning of young conifer plantations was begun.

Report of the Forest Products Research Board for the Year 1932. H.M. Stationery Office. Price 4*s*.

THE Chairman of the Board emphasizes that a definite advance has been made in fundamental research into those growth characters of wood which influence its strength, permeability, and other properties.

As usual, the report deals comprehensively with the many subjects of research in progress. Only a few can be referred to. Kiln experiments on a large scale have been made on ash, beech, elm, Lowland fir (*Abies grandis*), hornbeam, Maritime pine, European spruce, oak, Scots pine, and Sitka spruce. Maritime pine seasoned well, spruce almost as well, Sitka spruce had a tendency to rib, and *Abies grandis* suffered from splitting of the knots. Preliminary results from air-seasoning experiments are stated. Air-seasoning piles of softwood 6 feet wide dried from a green condition to 20 per cent. moisture content in one to two months in the case of boards of 1-inch thickness, and three months in the case of 2-inch planking. It was found that 1-inch green oak boarding dried to 25 per cent. moisture content between May and October 1931, and it is believed that 2-inch hardwoods can be satisfactorily seasoned in eighteen months. An investigation into the relation between structure of the wood of ash and its mechanical strength has produced the conclusion that the width of annual rings is not of fundamental importance in assessing the strength of the timber. The latter depends principally on the amount of wood substance; hence the percentage of summerwood is of importance. A method has been evolved for estimating the mechanical strength of ash which takes into account the amount of wood substance and its distribution as measured by the percentage of summerwood. A similar investigation has been started for Sitka spruce. The investigation into dry rot has been continued in the experimental building devoted to this purpose. In the 'bad construction' room—hollow floor with no ventilation—the fungus covered the greater part of the flooring eighteen months after inoculation. Alternate boards were removed and replaced by boards of Canadian *Thuja plicata* and *Tsuga heterophylla*. After nine months there were slight signs of attack upon the hemlock, but red cedar was free from the fungus. The Bulletin on *Dry Rot in Wood* has been revised, and reissued.

The advisory work of the Board is becoming increasingly important both to official bodies such as H.M. Office of Works, London County Council, and to private firms and individuals. The work for the Empire Overseas is also described.

Interim Report of the Inter-departmental Home-grown Timber Committee, 1933. H.M. Stationery Office. Price 4*d.*

THIS Committee was appointed by the Forestry Commissioners in December 1931. The neglect of forestry on most private estates is discussed. The causes are stated to be high taxation, the break-up of estates, the high cost of transport to consuming centres, and intermittent marketing. This neglect has also spread to marketing, which is generally unsatisfactory. There are, however, estates which are notable exceptions, where the woods are well managed and a local market has been built up. This is regarded as evidence that much more could be done. Now that estates are smaller in size co-operative marketing through a central organization in touch with various trades using wood is advocated. The Committee have reached the conclusion that they can best attain their object by investigating and making known the timber requirements of certain selected trades and the supplies of suitable timber available to meet them. They have selected the box-making and mining timber trades. It is considered that when it is known what proportion of the timber required by any trade can be supplied from home sources, there will be a case for rationing the amount of foreign timber used by these industries, and for revising the railway rates applicable to the home supplies. It is stated that if full use was made of existing home woods 40,000 men would be absorbed. Reference is made to the unfortunate effect of the exemption of mining timber from the 10 per cent. import duty, since timber imported as pit-props is freely used for the manufacture of boxes, wood-wool, &c. There are appendixes giving home supplies available, annual consumption, timber imported, summary of the Committee's investigations, and uses of home-grown timbers.

Journal of the British Wood Preserving Association, vol. iii, 1933. Price 7*s.* 6*d.*

THIS publication contains the papers read at the Association's meetings and the discussions which followed. They include: 'Timber Preservation from the Estate Agent's Point of View', by Mr. S. A. Kelly; 'Some Experiments on the Control of Dry rot in Floors', by Mr. A. H. Dewar; 'Paint and Varnish as Wood Preservatives', by Dr. L. A. Jordan; 'Preservative Treatment of Douglas fir Sleepers in the Sudan', by Mr. J. Thompson; and 'The Preservation of Railway Sleepers', by Mr. J. Bryan.

Zeitschrift für Weltforstwirtschaft, Band I, Heft 1. Oktober 1933.

THIS is the first number of a new periodical edited by Professor Heske. In an introductory note the objects in view are stated. Until recently, forest management on a sustained yield basis existed in only a few Middle European countries. There is now interest in all parts of the world in such management, and the object of this journal will be to spread the knowledge and experience gained by the countries with a long history of forest management, and particularly by Germany. The present issue contains articles on Italian Forest Policy and Forestry in Lettland and Estland. There are summaries in English.

Benmore.

THIS is the title of a brochure which describes the beauties and objects of interest of the Benmore Estate which was presented by Mr. Harry George Younger to the nation. Most of the estate is under the administration of the Forestry Commission, but

the policies which are of great interest to botanists and horticulturists are under the control of the Regius Keeper of the Royal Botanic Garden, Edinburgh. Over 200 species of the genus Rhododendron have been planted, and a list of some of the rarer shrubs and trees is given. Puck's Glen which is open to the public is described. It is a beautiful spot and contains the rest-hut erected as a memorial to Sir Isaac Baley Balfour. Brief descriptions are also given of the forest garden, the woods and plantations, and the arboretum. The mansion-house is divided into two sections, one of which is assigned to a school for working forest apprentices, and the other is reserved as a hostel for the reception of members of any University Senatus, lecturers, graduates, and students in botany or forestry or allied sciences. The *per capita* inclusive tariff is three guineas per week or 10*s*. 6*d*. per day: there are reduced rates for students nominated by Universities and other Institutions subscribing £10 annually. The Prospectus can be obtained from the Forestry Commission (Scotland), 25 Drumsheugh Gardens, Edinburgh. The brochure is illustrated by many beautiful photographs.